636

JOURNAL OF ANIMAL SCIENCE

Published Quarterly

by the

American Society of Animal Production

THE JOHN CREERAR
FEB 27 1953
LIBRARY

FEBRUARY

1953

Volume 12 Number 1

EDITORIAL BOARD

L. E. CASIDA, *Editor and Chairman*
J. K. LOOSLI, *Associate Editor*

E. P. REINEKE (1953)
R. H. BURNS (1953)
I. W. RUPEL (1954)
WISE BURROUGHS (1954)
W. D. GALLUP (1955)
L. N. HAZEL (1955)
W. M. BEESON (1956)
R. W. BRAY (1956)

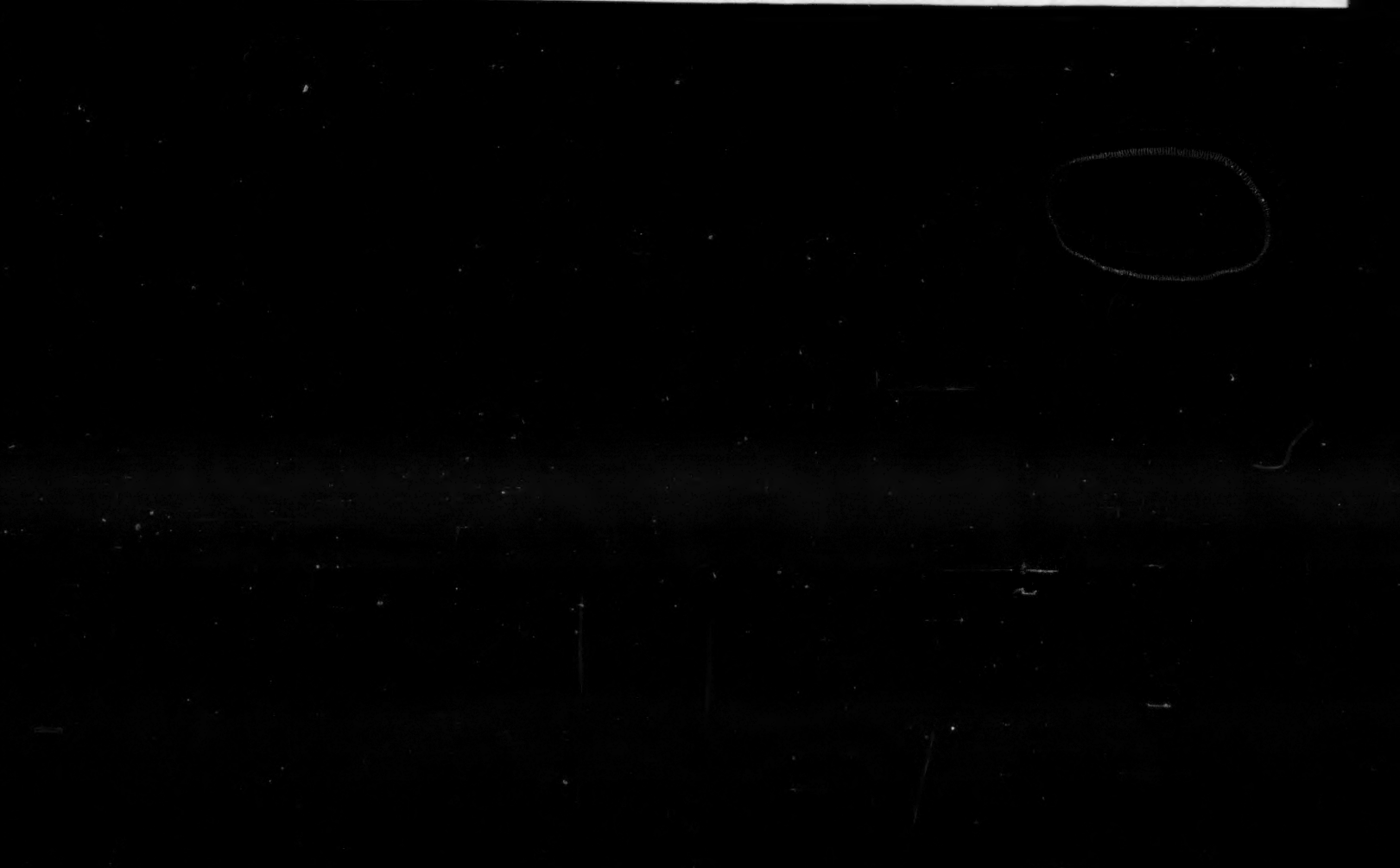
J. I. MILLER, *Business Manager*

* Terms expire on December 31 of years indicated

OFFICERS OF THE SOCIETY

M. L. BAKER, *President*
A. E. DARLOW, *Vice President*
J. I. MILLER, *Secretary, Treasurer*
J. E. FOSTER, *North-Atlantic Vice President*
C. M. KINCAID, *Southern Vice President*
J. L. VAN HORN, *Western Vice President*

Entered as second class matter under act of March 3, 1879, THE JOURNAL OF ANIMAL SCIENCE is published during February, May, August, and November by the Boyd Printing Company, Inc., 372–374 Broadway, Albany 7, N. Y. For Volume 12 (1953) domestic subscription price is $6.00; rest of North and South America is $6.50; and other places $7.00. Send your subscription to the publishers, 372–374 Broadway, Albany 7, New York or to J. I. Miller, Department of Animal Husbandry, Cornell University, Ithaca, N. Y. Make check payable to the American Society of Animal Production. Foreign subscribers please remit by International money order or by a draft on a New York bank. Notices of change of address should be in the hands of Dr. Miller 40 days previous to month of issue, to insure prompt delivery. Missing copies, owing to change in address cannot be supplied unless adequate notice has been given. Subscribers or members failing to receive a number of the JOURNAL should notify the Business Manager within 90 days of publishing date. Missing copies will be replaced only if due to error on the part of the Business Manager or printing company.



JOURNAL OF

ANIMAL SCIENCE

Published Quarterly

by the

American Society of Animal Production

FEBRUARY

1953

Volume 12 Number 1

CONTENTS

	Page
The Relationship of Serum Protein Bound Iodine Levels to Rates of Gain in Beef Cattle. H. O. Kunkel, R. W. Colby and Carl M. Lyman	3
Kepeatability, Heritability and the Effect of Level of Milk Production on the Occurrence of First Estrus After Calving in Dairy Cattle. Durward Olds and D. M. Seath	10
Effect of Sulfur Dioxide-Silage on Vitamin Excretion by Ruminants. A. E. Teeri, D. Josselyn, N. F. Colovos and H. A. Keener	15
Terramycin Supplement for Dairy Calves. A. M. MacKay, W. H. Riddell and R. Fitzsimmons	19
The Effect of Feeding Sucrose to Beef Cattle and Swine on the Dressing Percentage and Quality of Meat. E. B. Wilcox, M. B. Merkley, L. S. Galloway, D. A. Greenwood, W. Binns, J. A. Bennett and L. E. Harris	24
Occurrence of Estrus in Sows Following Parturition. L. N. Baker, H. L. Woehling, L. E. Casida and R. H. Grummer	33
Heritability of Gain in Different Growth Periods of Swine. Cecil T. Blunn, Guy N. Baker and L. E. Hanson	39
Effects of Certain Antibiotics and Vitamin B_{12} on Pantothenic Acid Requirements of Growing-Fattening Swine. Damon V. Catron, Robert W. Bennison, Helen M. Maddock, Gordon C. Ashton and Paul G. Homeyer	51
Development of Practical Synthetic Milk Formulas for Baby Pigs. Damon V. Catron, Leroy F. Nelson, Gordon C. Ashton and Helen M. Maddock	62
Dehydrated Alfalfa and Antibiotic Supplements in Gestation-Lactation Rations for Swine. J. G. De Pape, William H. Burkitt and A. E. Flower	77
Raising Baby Pigs on Dried Skim Milk: Effect of the Addition of Aureomycin and of Lard. Harold E. Schendel and B. Connor Johnson	84
Comparison of Anti-Bacterial and Anti-Yeast-Mold Antibiotics with Baby Pigs in the Presence of Several Levels of B Vitamins. Harold E. Schendel and B. Connor Johnson	88
Penicillin and Strentomycin Affect the Microflora of the Intestinal Tract of Pigs. J. H. Bridges, I. A. Dyer and J. J. Powers	96
Supplementation of a Corn-Meal and Bone Scrap Ration for Weanling Pigs. R. E. Bloss, R. W. Luecke, J. A. Hoefer, F. Thorp, Jr. and W. N. McMillen	102
The Influence of Heat Treatment and Solvent Upon the Nutritive Value of Soybean Oil Meal for Swine. D. E. Becker, C. R. Adams, S. W. Terrill and R. J. Meade	107
Transmittance of Foreign Organic Compounds from the Feed to the Flesh of Swine. Paavo Roine, Matti Antila and Inkeri Suhonen	117
Experimental Test of Predictions of Inbred Line Performance in Crosses. James V. Craig and A. B. Chapman	124
Environmental Factors Affecting Body Size and Conformation in Rambouillet Yearling Ewes. Daniel W. Cassard, P. W. Gregory, J. F. Wilson, W. C. Rollins and W. C. Weir	140
Selecting Lambs Under Farm Flock Conditions. H. A. Karam, A. B. Chapman and A. L. Pope	148
A Rapid Method for the Estimation of Clean Fleece Weight with the Aid of a New Wool Density Device. Khalid T. Ali, P. E. Neale and William D. McFadden	165
The Effects of Hormones on the Growth and Fattening of Lambs. T. M. Means, F. N. Andrews and W. M. Beeson	176
The Effects of Various Methods of Estrogen Administration on the Growth and Fattening of Wether Lambs. F. N. Andrews and W. M. Beeson	182
Protein Requirements of Ewes During Breeding and Pregnancy. Earle W. Klosterman, D. W. Bolin, M. L. Buchanan, F. M. Bolin and W. E. Dinusson	188
The Utilization of Ammoniated Industrial By-Products and Urea by Sheep. A. D. Tillman and R. W. Swift	201
The Fecal and Urinary Excretion of Certain B Vitamins by Sheep Fed Hay and Semi-Synthetic Rations. P. B. Pearson, Lee Struglia and Ivan L. Lindahl	213
The Use of Salt as a Regulator of Protein Supplement Intake by Breeding Ewes. W. C. Weir and R. F. Miller, Jr.	219
Proceedings of the Forty-Fourth Annual Meeting of the Society	226
President's Address	226
Minutes of the Business Meeting	227
Memorials	235
A. D. Weber Portrait	238
1952 Morrison Award	241
1952 American Feed Manufacturers Association Award	243
Chairmen of Committees and Programs and Special Assignments for 1953	244
News and Notes	245

Contents of previous issues of the JOURNAL OF ANIMAL SCIENCE are indexed in the Agricultural Index which is available in most libraries and in the November issue of each complete volume of the JOURNAL.

THE RELATIONSHIP OF SERUM PROTEIN BOUND IODINE LEVELS TO RATES OF GAIN IN BEEF CATTLE[1]

H. O. KUNKEL, R. W. COLBY, AND CARL M. LYMAN[2]

Texas Agricultural Experiment Station[3]

ATTEMPTS to predict the future gains of young animals in the feed lot on the basis of traditional judging procedures have not been fruitful. Although Hankins and Burk (1938) reported a finding of a fairly high correlation between feeder grade and the number of days required to reach a certain slaughter grade, there was little or no relationship between feeder grade and subsequent gains of cattle in the feed lot ($r=0.09$). Other workers (Johnson, 1944; Patterson *et al.*, 1949; Knapp and Clark, 1951) have reported similar findings with lambs and with record of performance steers.

The desirability of having an index which will predict future gains of immature beef cattle is self-evident. Thus experiments were begun in this laboratory in order to find a biochemical or physiological measure of the potential rate of gain of a calf. Digestion trials (Baker, Colby and Lyman, 1951) suggested that differences in rates of gain are not due to any large extent to individual differences in digestive powers of the animals. It would appear that the great differences that exist between animals in their ability to make gains lies in their utilization of food after it is absorbed. In an attempt to find an index to this utilization, tests were made of levels of various constituents in blood of beef cattle. Blood urea, non-protein nitrogen, creatine, creatinine, glucose, and cholesterol levels, however, revealed no significant correlation with rates of gain (Colby *et al.*, 1950).

It is likely that feed utilization as well as growth rate is under endocrine regulation. Long *et al.* (1952) have reported the results of analyses for serum protein bound iodine (used as an index of thyroid activity) in blood samples from dairy and beef cattle and concluded that highly significant differences exist between certain

[1] This investigation was conducted in cooperation with the Bureau of Animal Industry, United States Depaartment of Agriculture, as a part of the Southern Regional Beef Cattle Breeding Project S-10.

[2] The authors are deeply indebted to the Reid Brothers, Fort Davis, Texas, and Mr. Jack V. Williams, Paint Rock, Texas, for the loan of cattle for experimental purposes, to Dr. Bruce L. Warwick and Mr. M. W. Hazen, Bluebonnet Farm, McGregor, Texas, and Mr. L. A. Maddox, Jr., and Dr. H. R. Crookshank of the PanTech Farms, Texas Agricultural Experiment Station, for their assistance and cooperation in sampling cattle in feeding trials at their respective stations, to Priscilla Gougler for technical assistance, and to Carl Menger, a student of Texas A. and M. College, for assistance in the care and management of the experimental animals.

[3] Departments of Biochemistry and Nutrition and Animal Husbandry, College Station, Texas.

636.06103
46

breeds. The dairy breeds had serum protein bound iodine levels higher than those of the beef breeds. It is the purpose of the present work to present evidence which indicates that a relationship between rate of gain and protein bound iodine does exist and hence might be used to predict rate of gain in immature beef cattle.

Materials and Methods

A total of 42 Herefords, consisting of 29 bulls and 13 heifers, and 12 Aberdeen Angus bulls aged 8–11 months were used in the rate of gain studies. Ten of the Hereford bulls were fed individually at College Station and received an average diet consisting of 25% milo, 12% cottonseed meal, 32% cottonseed hulls, 21% prairie hay and 10% alfalfa. The remaining animals were fed as groups at the Bluebonnet and PanTech Farms with diets containing 15% cottonseed meal, 20–25% sorghum grains, 50–60% Johnson grass and sorghum hays with alfalfa or alfalfa leaf meal making up the remainder of the diet. In all cases the diet components were ground and thoroughly mixed before feeding. The individually fed bulls were allowed freedom of a pen, and twice daily they were placed in individual stalls for feeding. Accurate feed consumption records were kept. The remaining bulls were self-fed in groups of 3 to 7 animals and the heifers were selected from a group of 27 fed together. The cattle were weighed every 28 days.

Blood samples for protein bound iodine determination were collected by venepuncture and allowed to clot at room temperature. The sera were separated by centrifugation and stored at —10° C until triplicate analyses were made. The protein bound iodine was determined by the method as essentially described by Salter and McKay (1944) with modifications and calculations applied as suggested by Moran (1952). Because difficulty in calibration of the method was encountered at times, all serum samples from each group of animals were analyzed as nearly as possible at one time.

Simple correlations (Snedecor, 1946) were calculated for each group of animals.

Results

Individually Fed Calves

The 10 individually fed Hereford bull calves with initial weights of 430–610 lb. were fed for a period of 164 days following an adjustment period of 3 weeks in the feed lot. The levels of serum protein bound

iodine were determined in samples taken at 10 days and at 50 days following the beginning of the experimental feeding period. Since the method of iodine analysis had not been sufficiently developed at this time to give a precision with less than 10% variation, the values at 10 and at 50 days were averaged so that protein bound iodine levels given in table 1 are the means of 6 determinations. It may be seen from these data that the protein bound iodine levels showed a signifi-

TABLE 1. THE RELATION OF PROTEIN BOUND IODINE TO RATE OF GAIN AND FEED EFFICIENCY IN INDIVIDUALLY FED HEREFORD BULLS

Animal No.	Protein bound iodine μg/100 ml serum	Daily gain lb.	Efficiency lb. feed/lb. gain
111	3.5	2.58	7.24
131[1]	3.7	2.30	7.30
1	3.9	2.46	7.77
135	4.1	2.54	7.64
2	4.3	2.44	8.04
132	4.3	2.29	8.12
22	4.5	2.39	7.61
139	4.6	2.30	8.01
9	4.8	2.26	8.33
33	5.1	2.24	8.21
Average	4.28	2.38	7.83
Standard deviation	0.50	0.26	0.38
Coefficient of variation[2]	11.7%	10.9%	4.9%
Correlation	P.B.I./Gain −0.69*	P.B.I./Efficiency 0.84**	Gain/Efficiency −0.66*

[1] Animal No. 131 was dehorned following a horn injury on the 128th day of the feeding period.

[2] $\frac{\text{Standard deviation}}{\text{Average}}$ = Coefficient of variation.

* $P<0.05$

** $P<0.01$

cant negative correlation of −0.69 with daily gain. An even higher and more statistically meaningful correlation was found with feed efficiency as expressed as pounds of feed consumed per pound of gain. In this group of animals the lower elvels of protein bound iodine were found in animals making the greatest and most efficient gains.

Group Fed Calves

In view of the data obtained with individually fed calves, it was of interest to see if a similar relationship would hold for group fed animals. Blood samples were obtained from 8 Hereford bulls (initial weight of

440–600 lbs.) and 13 Hereford heifers (initial weight 350–520 lbs.) representing 2 sire groups at the Bluebonnet Farm. The blood samples were taken the 30th day of a 154-day feeding period. The data from these calves are summarized in table 2. With the heifers, the protein bound iodine levels again showed a significant correlation with rate of feed lot gain, but no definite relationship appeared in the data with the bulls. It is to be noted, however, that the variation in both the protein bound iodine levels and the rates of gain of the bulls is relatively small.

Blood samples were also obtained at the PanTech Farms from a group of 11 Hereford and 12 Aberdeen Angus bull calves representing 3 sire groups in each breed. These samples were taken on the 85th day of a 140-day feeding period in order to make a preliminary interbreed

TABLE 2. PROTEIN BOUND IODINE LEVELS AND RATES OF GAIN IN GROUP-FED HEREFORD BULLS AND HEIFERS (BLUEBONNET FARMS)

		Protein bound iodine μg/100 ml serum			Gain, lb./day			
Sex	No. of Animals	Average	S.D.	Coefficient of variation	Average	S.D.	Coefficient of variation	Correlation P.B.I./gain
Bulls	8	3.93	0.31	7.9%	2.58	0.18	6.8%	−0.36
Heifers	13	3.89	0.62	13.3%	1.59	0.21	16.0%	−0.55*

* P=0.05

comparison. At first, the results with this group did not appear to agree with the observations described above. The data did not reveal any significant linear correlations (Herefords: r=0.10; Angus: r=−0.36; all animals: r=−0.14), although the wide variations in both protein bound iodine levels and rates of gain were observed. However, when the data are considered from a point of view that there may be an optimal level of protein bound iodine associated with the highest gains, a distinct relationship is evident (table 3). Apparently the optimum level of protein bound iodine under conditions of this test was somewhere between 4.0 and 4.9 μg per 100 ml. serum. Animals whose protein bound iodine deviated from this range had lower rates of gain.

Discussion

It is suggested that the level of serum protein bound iodine may be used as a partial index of the potential efficiency of feed utilization or of the potential feed lot gain in immature beef cattle for the following reasons: The groups of calves which showed the wider variations in

protein bound iodine exhibited the wider ranges in rates of gain. The samples of blood from the individually fed bull calves and the Bluebonnet Farm calves were taken early enough that it may be said that the feed lot gains were subsequent to the protein bound iodine analyses.

TABLE 3. THE RELATION OF PROTEIN BOUND IODINE TO RATE OF GAIN IN GROUP FED BEEF BULLS (PAN TECH FARMS)

Animal No.	Breed	Initial wt. lbs.	Protein bound iodine μg/100 ml serum	Daily gain lb.
2–1	Hereford	627	2.9	2.08
2–4	Hereford	453	3.1	2.76
22–105	Angus	718	3.5	2.19
2–2	Hereford	703	3.6	2.54
28–3	Hereford	457	3.6	2.56
28–4	Hereford	431	3.8	2.65
21–6	Angus	649	4.1	2.86
16–2	Hereford	516	4.1	2.94
36–6	Angus	519	4.2	2.93
36–7	Angus	396	4.4	2.98
28–2	Hereford	498	4.4	3.33
36–5	Angus	525	4.5	2.86
2–3	Hereford	579	4.6	2.85
21–8	Angus	460	4.8	2.70
16–3	Hereford	550	4.8	2.69
28–1	Hereford	493	4.9	3.04
22–106	Angus	520	4.9	2.52
22–107	Angus	543	5.0	2.46
22–104	Angus	424	5.0	2.24
21–7	Angus	659	5.4	2.53
36–8	Angus	447	5.4	2.59
16–1	Hereford	515	5.8	2.07
21–5	Angus	605	6.2	2.19
Average	Both	534	4.48 (0.83)[1]	2.63 (0.33)
Average	Angus	539	4.78 (0.71)	2.59 (0.29)
Average	Hereford	529	3.93 (0.86)	2.68 (0.38)
Coefficient of variation	Both		21.9%	14.2%

[1] Standard deviation.

Finally, the evidence indicates that definite correlations may be established between the protein bound iodine level and the relative feed lot gain.

That there should be an optimum level of protein bound iodine commensurate with good feed lot gain is to be expected if one assumes that this level is an index of thyroid activity. Unpublished studies in this laboratory have indicated this to be true, for a highly significant cor-

relation between the level of protein bound iodine and the rate of metabolism of male beef calves has been observed. Hypothyroidism has been associated with dwarfism and hence with a low rate of gain in cattle (Carroll *et al.*, 1951). It is also logical that even a mildly hyperthyroid state would result in decreased feed efficiency and hence in a decreased rate of gain in the feed lot. Thus within limited groups of closely related animals it would not be unlikely that one might find a negative linear correlation between protein bound iodine and rate of gain in one group, a positive correlation in another, or no significant correlation at all in a third group. This is evident in the data presented here. The data in table 1 demonstrate the first case. If one disregards the data from animal No. 16–1, the Hereford data in table 3 support the second case and the Bluebonnet Hereford bulls, (table 2) show the lack of significant correlation either linear or curvilinear.

This report has of necessity been limited to preliminary studies. These data do not answer the question as to what the optimum protein bound iodine level actually is, for age, breed, managerial conditions and environment may have their effect on this level. The effects of the pretest environment on the protein bound iodine may have been reduced in this study, because blood samples were not taken until the animals had been under feed lot conditions for a month or more. Also, the effect of varying levels of other endocrine secretions have not been considered in this study thus far. Further investigation is required to elucidate these points.

Summary

The serum protein bound iodine levels have been determined in a total of 54 beef calves, 8–11 months of age, in 3 feeding trials. These levels were compared to subsequent or concomitant feed lot gain.

The results indicate that groups of Hereford and Aberdeen Angus calves which show a wide variation in protein bound iodine exhibited a wide variation in rate of gain. In 10 individually fed Hereford bulls, a high correlation between efficiency of gain and this iodine level was evident. Under certain conditions a negative correlation between the level of protein bound iodine and feed lot gain was observed. A study of a group of Aberdeen Angus and Hereford bulls indicates that this negative correlation exists only in animals which have an optimal or higher level of protein bound iodine. A low level may be accompanied by lowered rates of gain.

Literature Cited

Baker, J. P., R. W. Colby and C. M. Lyman. 1951. The relationships of feed efficiency to digestion rates of beef cattle. JOURNAL OF ANIMAL SCIENCE 10:726.

Carroll, F. D., P. W. Gregory, and W. C. Rollins. 1951. Thyrotropic-hormone deficiency in homozygous dwarf beef cattle. JOURNAL OF ANIMAL SCIENCE 10: 916.

Colby, R. W., J. H. Ware, J. P. Baker, and C. M. Lyman. 1950. The relationship of various blood constituents to rate of gain in beef cattle. JOURNAL OF ANIMAL SCIENCE 9:652 (Abstract).

Hankins, O. G. and L. B. Burk. 1938. Relationships among production and grade factors of beef. U.S.D.A. Tech. Bull. 665, 39 pp. illus.

Johnson, L. E. 1944. The relationship of feeder grade, initial weight, total gain, finished grade and carcass grade of lambs. JOURNAL OF ANIMAL SCIENCE 3:224.

Knapp, B. Jr., and R. T. Clark. 1951. Genetic and environmental correlations between weaning scores and subsequent gains in the feed lot with record of performance steers. JOURNAL OF ANIMAL SCIENCE 10:365.

Long, J. F., L. O. Gilmore, G. M. Curtis, and D. C. Rife. 1952. Bovine protein bound iodine and its relation to age and breed. Jour. Dairy Sci., 35:603.

Moran, J. J. 1952. Factors affecting the determination of protein bound iodine in serum. Anal. Chem., 24:378.

Patterson, R. E., J. H. Jones, J. J. Bayles and R. V. Turnbough. 1949. Performance testing and progency testing of beef breeding stock as an aid to selection. JOURNAL OF ANIMAL SCIENCE 8:608 (Abstract).

Salter, W. T., and E. A. McKay. 1944. Iodine in blood and thyroid of man and small animals. Endocrinology 35:380.

Snedecor, G. W. 1946. Statistical Methods, 4th Edition, Iowa State College Press, Ames, Iowa.

REPEATABILITY, HERITABILITY AND THE EFFECT OF LEVEL OF MILK PRODUCTION ON THE OCCURRENCE OF FIRST ESTRUS AFTER CALVING IN DAIRY CATTLE[1]

DURWARD OLDS and D. M. SEATH[2]

Kentucky Agricultural Experiment Station

IT is apparent that reproductive efficiency in dairy cattle may be influenced either by the length of time from calving to first heat or by the number of services required for pregnancy. The effect which level of milk production has on these two factors is of considerable interest to dairymen and research workers. Gaines (1927) studied 4,671 Guernsey A. R. records and found a very low correlation ($r = 0.039 \pm 0.01$) between milk production for the first calendar month of the lactation and the length of time from calving to conception. Lewis and Horwood (1950) reported that cows beginning a lactation at a high level of production were not rebred as quickly and did not conceive as readily as lower producing cows. In like manner, New Zealand workers (Anonymous, 1940–41) observed indications that better fertility occurred in lower producing herds. Clapp (1937) and Herman and Edmondson (1950) in efforts to arrive at more specific effects of milk production, found no correlation between level of milk production and the interval from calving to first heat. With similar purpose in mind, Boyd (1951) studied the records of 29 Kentucky dairy herds and found no significant correlation between level of milk production for the first 120 days of lactation and the number of services required for pregnancy.

Chapman and Casida (1934) reported that the average period from parturition to first estrus was 69 ± 39 days. They also stated that within a fairly wide range of variation the cows tended to have a similar length of time between calving and first estrus at different calving intervals. This influence of individual physiological characteristics has not been sufficiently investigated. It would seem likely that such individual characteristics may be heritable.

The present study was made in order to clarify further the information relative to the effect of milk production on breeding efficiency, to supplement the Chapman and Casida estimates (1934) regarding repeat-

[1] The investigation reported in this paper is in connection with a project of the Kentucky Agricultural Experiment Station and is published by permission of the director.

[2] The authors wish to acknowledge the assistance of Gene Holtzclaw and James Perkins in making the tabulations for this study.

ability of the time interval from calving to first subsequent estrus, and to provide some information on the heritability of this characteristic.

Experimental Procedure

Breeding records and D.H.I.A. production records were obtained from the Kentucky Agricultural Experiment Station dairy herd for a period of 20 years (1928 to 1947 inclusive). Data on the number of days between calving and first subsequent estrus were obtained for 472 normal parturitions of 210 cows. The animals were checked at least twice a day for heat periods and all heat periods were recorded regardless of whether the cows were bred. In this sort of data, covering a relatively long period of time, some errors may have been made. However, since studying the records and talking with persons associated with the herd during that time, the authors feel confident that the records are reliable. The same herdsman was in charge during all but the last 4 years of this period and he had a reputation for keeping detailed and accurate records.

Milk production records for 120 days following each parturition were converted to mature equivalent using U.S.D.A. factors and 4% F.C.M. using Gaines' (1928) formula. Both the production records in pounds and the time intervals in days from calving to first heat were summarized by the analysis of variance and intraclass correlation techniques as outlined by Snedecor (1950).

The correlation between milk production and length of time from calving to first heat was determined. In calculating heritability of the interval from calving to first heat, the first available records of the dams were correlated with the first available records of the daughters on an intra-sire basis. Heritability was then obtained by doubling the intra-sire regression coefficient as described by Lush (1940). This procedure was also applied to data in which the average of all available records was used, instead of single records, for each dam and daughter.

Results and Discussions

The average number of days from calving to first estrus for 472 normal parturitions of 210 cows was 32.1 ± 18.6 days. The application of analysis of variance to the data showed that there was significantly more variation among cows than there was within records of the same cows. This indicates that individual cows have a tendency to repeat a similar length of time between calving and first estrus at successive

parturitions. The extent of this tendency as shown by the intraclass correlation or "repeatability" was 0.29 or 29.0 percent for single records of the same cow. It appears, therefore, that 29 percent of the variance in the records on time from parturition to first estrus would be eliminated by removing differences between cows. This repeatability seems rather high in view of the fact that the authors previously reported (1951) that the repeatability of the estrous cycle length was only 6.9 per cent. However, the fact that the calving-to-estrus intervals are longer and have a greater standard deviation than estrous cycle lengths (32 ± 18.6 days as compared to 21.8 ± 4.6 days) may have had a bearing in producing a relatively high repeatability.

The correlation between milk production for the first 120 days (M.E. 4% F.C.M.) and number of days from calving to first heat was 0.095 which was significant at the 5 percent level of probability. The coefficient of determination (r^2) indicated that level of milk production accounted for only 0.9 percent of the variation in time from calving to first heat. The general trend was revealed by the regression ($b=0.0015\pm0.0007$; $P=<0.05$) which showed that for each additional 1,000 lb. of 4% F.C.M. produced in the first 120 days of the lactation, there was a period of about 1.5 more days between calving and first heat. This 1,000 lb. increase in production for a 120-day period would be an average increase of 8.3 lb. per day. As indicated by the small correlation, however, there were numerous exceptions to this general trend.

The first available calving-to-estrus records of 164 daughters of 25 bulls were correlated with similar records of their dams. The overall correlation was 0.145 and the intra-sire correlation was 0.136. Neither of these correlations was quite significant at the 5 percent level of probability. However, when the average of all available records was used for each animal rather than first records, the overall correlation was 0.288 ($p<0.01$) and the intra-sire correlation was 0.182 ($p<0.05$). The dams and daughters had lifetime averages of about 2.3 calving-to-estrus intervals. The intra-sire regression was calculated from both sets of data and doubled, as proposed by Lush (1940), for estimating heritability. The estimate of heritability based on single records was 27 percent and that based on all records was 32.2 percent. As previously indicated, the intra-sire regression based on single records was not quite significant at the 5 percent level, however, that based on all records was significant at the 5 percent level. In view of the repeatability for single records of the same cow, which was 29 percent, this

heritability would appear to be a logical estimate. In other words, the relatively fixed physiological characteristics determining the interval from calving to first heat in individuals seem to be for the most part inherited, as indicated by the heritability estimates of 27 and 32 percent.

The variance between daughters of the same bulls was just as great as the variance between the averages of daughters by different bulls when only the first available calving-to-estrus intervals were considered for each animal. Therefore, it appeared that sires had no effect in transmitting these characteristics to their daughters. However, when all records were considered instead of single records, there was significantly more variation between the daughters of different bulls than between the daughters of the same bulls. The correlation between paternal half-sibs, when multiplied by four (Lush 1940), indicated that the heritability was about 31.1 percent. This is in close agreement with the heritability estimate based on the intra-sire regression of daughter on dam.

Summary

The average length of time from calving to first estrus for 472 normal parturitions of 210 cows was 32.1 ± 18.6 days. Analysis of the data indicated that individual cows had a tendency to repeat a similar length of time between calving and first estrus at successive parturitions. It appears that one previous observation on a cow would eliminate about 29 percent of the variance in predicting future performance in respect to the occurrence of heat after calving.

Level of milk production was found to account for about 0.9 percent of the variation in time from calving to first heat.

Heritability for time interval from calving to first estrus was estimated to be 27 percent when based on the intra-sire regression of daughter on dam using only the first available records for each animal. When all records were used, the heritability estimate was 32.2 percent. The correlation between paternal half-sibs indicated a heritability that was too small to be measured when based on single records but was 31.1 percent when all records were used.

References

Anonymous, 1940–41. Seventeenth Annual Report of the New Zealand Dairy Board. Invicta House. Wellington, New Zealand. pp. 32, 39.

Boyd, L. J. 1951. The Relationship Between Level of Milk Production and Breeding Efficiency in Dairy Cattle. Thesis. University of Kentucky.

Chapman, A. B. and L. E. Casida. 1934. Factors Associated With Breeding Efficiency in Dairy Cattle. Amer. Soc. Anim. Prod. Proc. pp. 57–59.

Clapp, H. 1937. A Factor in Breeding Efficiency of Dairy Cattle. Amer. Soc. Anim. Prod. Proc. pp. 259–265.

Gaines, W. L. 1927. Milk Yield in Relation to Recurrence of Conception. Jour. Dairy Sci. 10:117–125.

Gaines, W. L. 1928. The Energy Basis of Measuring Milk Yield in Dairy Cows. Ill. Agr. Exp. Sta. Bul. 308.

Herman, H. A. and J. H. Edmondson. 1950. Factors Affecting the Interval Between Parturition and First Estrus in Dairy Cattle. Mo. Agr. Expt. Sta. Res. Bul. 462.

Lewis, R. C. and Horwood, R. E. 1950. The Influence of Age, Level of Production and Management on the Calving Interval. The Quarterly Bul. Mich. Agr. Expt. Sta. 32:546–549.

Lush, J. L. 1940. Intra-Sire Correlations or Regressions of Offspring on Dam as a Method of Estimating Heritability of Characteristics. Proc. Amer. Soc. Anim. Prod. pp. 293–301.

Olds, D. and D. M. Seath. 1951. Repeatability of the Estrous Cycle Length in Dairy Cattle. Jour. Dairy Sci. 34:626–632.

Snedecor, G. W. 1950. *Statistical Methods*. Iowa State College Press. Ames, Iowa

EFFECT OF SULFUR DIOXIDE-SILAGE ON VITAMIN EXCRETION BY RUMINANTS[1]

A. E. Teeri, D. Josselyn, N. F. Colovos and H. A. Keener

New Hampshire Agricultural Experiment Station

AMONG the various methods of silage preservation, the use of sulfur dioxide is acquiring a position of considerable significance. Although somewhat disagreeable to handle, this product is gaining steadily in popularity because of its value in promoting the desired acidity quickly, in preserving carotene and in preventing protein decomposition (Knodt, 1950; Skaggs and Knodt, 1952). Aside from these factors, however, little is known regarding the effect of sulfur dioxide on the nutritional well-being of animals fed this type of silage. Such information, therefore, will be of considerable immediate value.

Since the synthetic activity of the rumen or intestinal microorganisms appears to be of considerable importance in ruminant nutrition (Teeri, *et al.*, 1950, 1951), it seemed desirable to determine what effect, if any, sulfur dioxide-preserved silage has on vitamin synthesis in the digestive tract of cows. It is the purpose of this report, therefore, to present the results of an investigation into the effects of this material on the fecal and urinary excretion, by ruminants, of nicotinic acid riboflavin and thiamine.

The vitamin content of sulfur dioxide-preserved silage after storage for six months is also reported.

Experimental

It has been indicated (Teeri, *et al.*, 1950) that fecal and urinary excretion values can be used, in a comparative sense, as a measure of vitamin synthesis by ruminants, when the animals are maintained on a constant daily intake. This technique was employed to compare the synthesis of nicotinic acid, riboflavin and thiamine in the rumen of cows when fed grass silage treated with five pounds of sulfur dioxide per ton with that occurring on rations consisting of field cured hay, grass silage without preservative, molasses grass silage, or molasses grass silage fed with 100 grams of limestone per day. The experimental animals consisted of three Ayrshires, approximately two years of age.

[1] Published with the approval of the Director of the New Hampshire Agricultural Experiment Station as Scientific Contribution No. 155.

TABLE 1. VITAMIN CONTENT OF THE ROUGHAGE WHEN FED[a, b]

Method of Preservation	Nicotinic Acid	Riboflavin	Thiamine**
	Micrograms/gram of dry matter		
Field cured	24.0	7.0	1.6
Silage	17.5	4.5	1.8
Silage+SO_2	20.0	10.0	1.0
Silage+Molasses	32.5	10.0	1.4

[a] Determined by microbiological assays (Teeri, *et al.*, 1950).
[b] Storage time, approximately 6 months.
** All thiamine differences are significant at the 1 percent level, with the one exception that the difference between field cured and silage is significant only at the 5 percent level.

Methods of collection, preservation and analysis of the urine and feces samples were as previously reported (Teeri, *et al.*, 1950).

Results and Discussion

Interpretation of vitamin excretory data in terms of rumen synthesis necessarily involves consideration of the daily vitamin intake. The roughages were assayed, therefore, for nicotinic acid, riboflavin and thiamine, and the results are presented in table 1. Since the same hay was used in all cases, these data present a comparison of the effects of method of preservation on the vitamin content of the roughage during storage. Probably the most significant fact to be learned from this information is that such effects differ greatly among the vitamins. What may be a good preservative for one vitamin may be destructive to another, and assessment of the value of such substances as sulfur dioxide and molasses must involve consideration of their effect on vitamin synthesis by the rumen microorganisms.

Daily vitamin intakes (table 2) were calculated from the data of table 1 and the average consumption figures for each ration.

TABLE 2. AVERAGE VITAMIN INTAKES

Ration fed	Nicotinic Acid	Riboflavin	Thiamine
		(Mg./day)	
Field cured hay	144.0	42.0	9.6
Silage	106.4	27.4	10.9
Silage+SO_2	121.6	60.8	6.1
Silage+molasses	160.0	49.2	6.9
Silage+molasses+limestone	160.0	49.2	6.9

Table 3 presents the average excretion values for nicotinic acid, riboflavin and thiamine as related to the various rations. As measured by total excretions, rumen synthesis of nicotinic acid was apparently uninfluenced by the ration. The decreased excretions which did occur when the ration consisted of sulfur dioxide-silage or silage without preservative merely reflected the decreased intake of this vitamin. In all cases excretions were considerably less than the daily intake a fact which adds strength to the previous suggestion (Teeri, *et al.*, 1950) that rumen synthesis of nicotinic acid generally is not of great importance to the bovine species.

While the average total excretion of riboflavin was essentially the same with silage as with field cured hay, correlation of these data with

TABLE 3. AVERAGE VITAMIN EXCRETIONS[a]

Ration fed	Nicotinic Acid	Riboflavin	Thiamine
		(Mg./day)	
Field cured hay	43.6	20.1	7.9
Silage	27.6	21.7	8.1
Silage+SO_2	37.1	30.2	9.1
Silage+molasses	44.7	25.8	8.2
Silage+molasses+limestone	45.0	21.4	6.8

[a] Urine+feces.

the vitamin intakes indicates that silage favors the rumen synthesis of riboflavin. This synthesis-favoring action is apparently uninfluenced by sulfur dioxide or by molasses.

Total thiamine excretion was greatest when the ration consisted of sulfur dioxide-silage. This fact assumes high significance when considered in relation to the very low intake of this vitamin. Evidently sulfur dioxide destroys much of the thiamine in the silage. Subsequently, however, it favors rumen synthesis of thiamine, thus counteracting the deficiency of this vitamin in the ration. A similar, though less pronounced, situation exists in the case of molasses silage, indicating the thiamine synthesis-favoring action of a high carbohydrate ration. The presence of limestone, however, nullifies this effect, probably because of the pH sensitivity of the thiamine-producing microorganisms.

Summary

Insofar as nicotinic acid, riboflavin and thiamine are concerned, in ruminant nutrition, sulfur dioxide appears to be a highly satisfactory

silage preservative. Although sulfur dioxide destroys much of the thiamine in the silage, it counteracts the deficiency by producing conditions in the rumen favorable to the synthesis of this vitamin.

The alkalinity resulting from the feeding of limestone is unfavorable to the intestinal or rumen synthesis of thiamine.

Literature Cited

Knodt, C. B. 1950. The sulfur dioxide preservation of grass silage. JOURNAL OF ANIMAL SCIENCE 9:540.

Skaggs, S. R., and C. B. Knodt. 1952. Sulfur dioxide preservation of forage crops. Jour. Dairy Sci. 35:329.

Teeri, A. E., D. Josselyn, N. F. Colovos, and H. A. Keener. 1951. Effects of method of preservation of roughage, and of cane or wood molasses, on vitamin excretion by cows. Jour. Dairy Sci. 34:299.

Teeri, A. E., D. Josselyn, N. F. Colovos, and H. A. Keener. 1951. Influence of the ration on the excretion of certain vitamins by ruminants. Jour. Dairy Sci. 34:1070.

Teeri, A. E., M. Leavitt, D. Josselyn, N. F. Colovos, and H. A. Keener. 1950. The effect of sulfathalidine on the excretion of vitamin B by ruminants. Jour. Biol. Chem. 182:509.

TERRAMYCIN SUPPLEMENT FOR DAIRY CALVES[1, 2]

A. M. MacKay, W. H. Riddell and R. Fitzsimmons
Vermont Agricultural Experiment Station

THE value of certain antibiotics in promoting growth in dairy calves is now quite well established. One of the most recent studied is terramycin. Voelker and Cason (1951) fed terramycin to calves at the rate of 30 mg. per 100 pounds body weight. An average gain of 63 pounds was noted for the supplemented calves as compared to 52 pounds for the controls. The length of feeding period is not mentioned. At the rate of 100 mg. daily, seven calves gained 28 percent over the controls. No increase in feed utilization efficiency was observed.

Considerable research has been done on the value of aureomycin for dairy calves. Rusoff (1950), Bartley *et al.* (1950), Loosli *et al.* (1951) and Murley *et al.* (1951) have proved the growth-stimulating properties of aureomycin and its value in checking scours. MacKay, Riddell and Fitzsimmons (1952) found that aureomycin had definite growth promoting effect even in the absence of scours.

The objectives of this investigation were to study the effect of feeding terramycin on the growth, efficiency of feed utilization, incidence of scours and general well-being of (1) dairy calves from birth to 12 weeks of age, and (2) older ruminating animals.

Trial I

Eighteen heifer calves of the four dairy breeds—Ayrshire, Guernsey, Holstein and Jersey—were placed on trial as they were dropped in the Experiment Station herd. Eight calves were allotted at random as controls while the remaining ten were fed a terramycin supplement. The length of the trial was 12 weeks.

The feeding schedule, calf starter ration and management practices were the same as reported previously, (MacKay, Riddell and Fitzsimmons (1952). A terramycin supplement containing 5 grams of terramycin hydrochloride per pound was used. The rate of feeding was such as to supply 30 mg. of terramycin hydrochloride per 100 pounds of body weight. Weekly adjustments were made for gain in weight. On this basis the calves in the supplemented group received from 19 to 82 mg. of terramycin hydrochloride daily. It was fed in the milk until

[1] This research was supported in part by a grant from the Chas. Pfizer & Co., Inc.
[2] Journal Series Paper No. 31, Vermont Agricultural Experiment Station.

the calves were consuming approximately one pound of starter daily after which it was added to the grain.

Results and Discussion

The weight gain and feed utilization data for the different breeds are shown in table 1.

Examination of the data shows that the calves in all breeds receiving the terramycin made greater average daily gains than the control animals. A straight comparison between groups is not possible due to

TABLE 1. AVERAGE WEIGHTS, CALF STARTER CONSUMPTION AND FEED UTILIZATION EFFICIENCY AT 12 WEEKS OF AGE

Group	No. of animals	Average Weights: Birth (lb.)	Average Weights: 12 Weeks (lb.)	Average Weights: Daily gain (lb.)	Ave. calf starter consumed (lb.)	Gain per lb. T.D.N. (lb.)
	(Holsteins)					
Control	5	90.6	215.9	1.49	136.5	.59
Supplemented	4	98.9	243.1	1.72	184.0	.58
	(Ayrshires)					
Control	2	81.5	185.5	1.24	114.5	.59
Supplemented	2	61.3	178.5	1.40	136.5	.62
	(Guernseys)					
Control	1	63.0	171.0	1.29	87.0	.71
Supplemented	2	67.5	184.3	1.39	153.5	.56
	(Jerseys)					
Supplemented	2	55.0	153.3	1.17	138.0	.51

the varying growth rates of the breeds. A comparison of the weights of the two groups at 12 weeks shows both to exceed the Ragsdale (1934) standard, the supplemented animals by an average of 40.9 pounds or 20.2 percent and the controls by an average of 25.9 pounds or 13.6 percent. This difference between the two groups was found to be statistically significant.

There was no significant difference in the feed utilization efficiency of the two lots. The supplemented calves made 0.55 pounds of gain per pound of T.D.N. as compared with 0.60 for the controls. The calf starter consumption of the terramycin-fed calves was higher than that of the control animals.

Scours were a minor factor in the experiment. This is in line with recent past history of calf raising in the herd. One mild case of scours

occurred in one of the control calves. The feces of the terramycin-fed calves appeared firmer than the controls.

A readily observable difference was noted in the general appearance of the calves fed terramycin. Early in the experiment they developed a smoother-coated appearance. This contrast was evident throughout the trial. There was also a significant increase in the appetite of the supplemented calves. Grain consumption commenced about two weeks earlier and increased steadily to the maximum of the four pounds allowed daily. At no time were any adverse results noted from the terramycin feeding.

The results with terramycin hydrochloride closely parallel those reported previously for aureomycin hydrochloride under similar feeding and management conditions. The rate of aureomycin feeding was approximately 35 mg. per 100 pounds of body weight. The aureomycin-fed calves averaged 38.1 pounds over the Ragsdale standard at 12 weeks of age as compared with 40.9 pounds for the terramycin calves. There appeared to be more effect on the appetite and a somewhat smoother appearance with the terramycin supplemented calves.

Trial II

Eight heifer calves, four Holstein and four Guernsey, were divided into two equal groups on the basis of breed, age and size. They were from six to nine weeks of age, a period when the rumen is beginning to function. Both groups had been raised on the regular feeding schedule for the Experiment Station calf herd. They were continued on a 20% calf starter until 4 months of age, followed by a growing ration until the end of the trial. Rate of grain consumption was between 3 and 4 pounds daily. Good quality hay and limited amounts of corn silage were also fed.

Group I was maintained as the control lot. To the grain of the calves in Group II was added a terramycin supplement to supply 24 grams of terramycin hydrochloride per ton of feed. On the basis of the amount of grain fed, the calves in the supplemented group received from 37.5 to 60 mg. of terramycin daily. There was an initial increase in growth of the supplemented over the control calves, but at the end of eight weeks there was little difference noted in rate of gain. At this time the groups were reversed so that Group II now consisted of the controls while Group I was the supplemented lot. The reversal period continued for eight weeks. At the end of the trial the calves were from 22 to 25 weeks of age.

Results and Discussion

The weight data and the average daily gain per calf for each period are shown in table 2. In the initial period the supplemented calves made an average daily gain of 1.89 lb. as compared to 1.77 lb. for the controls. There appeared to be an initial increase in gain during the first part of the period, declining gradually to the close of the period. The average daily gains for the 7th and 8th weeks of the period were almost identical, viz. 1.94 lb. for the controls and 1.93 lb. for the supplemented calves.

When the groups were reversed, the average daily gain of Group I increased from 1.94 lb. to 2.43 lb. during the first two weeks of the period on the terramycin supplemented ration. Following this there

TABLE 2. GROWTH AND AVERAGE DAILY GAIN PER CALF (FOR 8-WEEK PERIODS)

Period	Group	Ration	Ave. initial (lbs.)	Ave. 8 weeks (lbs.)	Average daily gain (lbs.)
Initial	1	Control	141.3	240.3	1.77
	2	Supp.	142.8	248.5	1.89
Reversal	2	Control	248.5	348.3	1.78
	1	Supp.	240.3	343.5	1.84

was a gradual decline with an average daily gain for the period of 1.84 lb. for the supplemented and 1.74 lb. for the controls.

While a limited number of animals was used in this phase of the trial and the increased growth with terramycin feeding was not significant, the stimulating effect of terramycin is of interest. Rusoff (1951) has reported a similar stimulating effect with aureomycin in older calves. In the initial period, the Group I supplemented calves appeared also to have a smoother appearance. With the reversal of the groups, these calves appeared to lose this bloom to some extent while the Group II calves, now receiving terramycin, showed improvement in smooth coated appearance. Scours were not a factor affecting growth in any of the calves.

Summary and Conclusions

The feeding of a terramycin supplement to young dairy calves, receiving a liberal ration of milk, calf starter and good quality hay, produced

a significant increase in growth, stimulated the appetite and improved the general appearance as compared to the controls.

Feeding terramycin supplement to older calves showed a lesser effect. After an initial increase in rate of growth for the first two weeks of feeding the growth rate gradually declined to the control level. Some improvement in general appearance was noted.

No conclusion can be drawn as to the effect of terramycin in the control of scours due to its very slight incidence in these trials.

Terramycin appears to be at least as effective as aureomycin in stimulating the growth of young dairy calves.

Literature Cited

Bartley, E. E., E. C. Fountaine and F. W. Atkeson. 1950. The effects of an A.P.F. concentrate containing aureomycin on the growth and well-being of young dairy calves. JOURNAL OF ANIMAL SCIENCE 9:646.

Loosli, J. K., R. H. Wasserman and L. S. Gall. 1951. Antibiotic studies with dairy calves. Jour. of Dairy Sci. 34:500. *Abstract*

MacKay, A. M., W. H. Riddell and R. Fitzsimmons. 1952. Feed supplement containing aureomycin and vitamin B_{12} for dairy calves. JOURNAL OF ANIMAL SCIENCE 11:341.

Murley, W. R., N. L. Jacobson, J. M. Wing and G. E. Stoddard. 1951. The response to aureomycin supplementation of young dairy calves fed various "practical" and restricted diets. Jour. of Dairy Sci. 34:500. *Abstract*

Ragsdale, A. C. 1934. Growth standards for dairy cattle. Missouri Agr. Expt. Station Bull. 336.

Rusoff, L. L. 1950. A.P.F. supplements for calves. JOURNAL OF ANIMAL SCIENCE 9:666. *Abstract*

Rusoff, L. L. 1951. Antibiotic feed supplement (aureomycin) for dairy calves. Jour. of Dairy Sci. 34:652.

Voelker, H. H., and J. L. Cason. 1951. Antibiotic studies with dairy calves. JOURNAL OF ANIMAL SCIENCE 10:1065. *Abstract*

THE EFFECT OF FEEDING SUCROSE TO BEEF CATTLE AND SWINE ON THE DRESSING PERCENTAGE AND QUALITY OF MEAT[1]

E. B. Wilcox, M. B. Merkley, L. S. Galloway, D. A. Greenwood, W. Binns, J. A. Bennett and L. E. Harris[2]

BATE-SMITH, 1948, showed that the treatment a pig receives a few hours before slaughter may alter the quality of the meat produced. Madsen (1943) found that feeding sugar to swine a few hours before slaughter had a beneficial effect on bacon keeping quality and increased the liver weight significantly. Gibbons and Rose (1950) have made studies of the effect on swine of fatigue and feeding under conditions normally found in Canadian packing plants. They found that the feeding of sugar to pigs a few hours before slaughter increased the size of the liver and improved the quality of the unsmoked Wiltshire sides. Studies by Ramsbottom *et al.* (1949) on the causes of "dark-cutting" beef have revealed that the incidence of the defect was reduced by proper preslaughter treatment of animals.

The purpose of this study was to determine the effects of feeding varying levels of sucrose to beef and swine for varying periods prior to slaughter on dressing percentage, color, texture, flavor, total carbohydrate content and pH of muscle and liver.

Procedure

Ninety-five beef cattle and 12 swine were fed varying amounts of sucrose for different time intervals before slaughter. In Series I, five grass-fed, two-year-old heifers were used. They had been raised at Opal, Wyoming on native hay. Feed was withheld 44 hours after which four of the five animals received by stomach tube a sugar solution containing 2, 4, 8 or 12 pounds of refined sucrose 6 hours before slaughter. The fifth animal served as a control and had access to water. Their carcases graded utility.

In Series II, 30 grade Hereford steers and heifers were fed, in the pens of Swift and Company at Burley, Idaho, for 80 days, a ration

[1] Taken in part from data of a thesis submitted by Margaret B. Merkley in partial fulfillment of requirements for the degree of master of science.

[2] Contribution from the Departments of Foods and Nutrition, Chemistry, Veterinary Science and Animal Husbandry. This study was financed by a grant from the Sugar Research Foundation. Sucrose was furnished by the Amalgamated Sugar Company and the Utah-Idaho Sugar Company. The cooperation of the employees of the Ogden plant of Swift and Company and of the Western Livestock Feed Association is acknowledged. Appreciation is extended to Bliss Crandall of Utah State Agricultural College for the statistical analyses.

consisting of raw potatoes, wet and dry beet pulp, rolled barley, ground wheat, cottonseed meal, chopped alfalfa hay and minerals. At the Ogden plant of Swift and Company the animals were divided into six lots of five animals each. Two lots of steers and two of heifers were given 6 or 12 pounds of sucrose per animal by stomach tube 30 hours before slaughter. The other two lots, one of steers and one of heifers, served as control animals. All animals had access to water during the holding period. All of the steers graded choice while the heifers graded choice or good.

In Series III, 60 grade Hereford steers except for a few grade Shorthorns were purchased as young feeders in Utah, Idaho and Wyoming. All steers were fed a basal ration of ground alfalfa hay, ground barley, dried beet pulp, minerals and molasses (fed at a 10 percent level of the total ration) for 90 days. The animals were then alloted at random to

TABLE 1. EXPERIMENTAL DESIGN FOR FEEDING BEEF CATTLE IN SERIES III

Sucrose fed daily per animal	0 lb.	2 lb.	4 lb.
Days fed	Control	3, 6, 9, 12	3, 6, 9, 12
Number of animals	20	5, 5, 5, 5	5, 5, 5, 5

the treatments as shown in table 1. One lot, the control animals, was handled according to current practice of Western Llvestock Feed Association. Two lots of steers were given 2 and 4 pounds of sucrose, respectively, per animal per day plus the basal ration fed by the Western Livestock Feed Association for 3, 6, 9 or 12 days. This made a total of five animals per treatment. The control animals were fed as a group and the animals receiving 2 or 4 pounds of sucrose were fed in each of two groups. The sugar was placed on top of the basal ration. All food was removed from the animals for about 30 hours before slaughter. Fresh water was available at all times. The carcass grades of all the steers were choice except for two which were prime.

Liver samples for all three Series were taken at the time of slaughter. The wholesale cut of rib roast was cut from the same side of each carcass after 72 hours storage in Swift's refrigerator at 38 to 40° F.; it was used for chemical and organoleptic tests.

Six litter mate, grade Duroc-Jersey and six litter mate, Chester-White pigs were fed a basal ration of protein supplement, ground alfalfa, ground barley, bone meal and salt. The Duroc-Jersey pigs

were fed the basal ration plus 0, 2, or 4 pounds of sucrose daily for 14 days prior to slaughter which made two animals per treatment. The Chester-White pigs were fed the basal ration plus 0 or 2 pounds of sucrose daily for 3 days prior to slaughter, making three animals per treatment. Each pig was fed individually. The last feeding of sucrose was 16 hours before slaughter.

Total sugars were determined by Oesting and Beach's modification of the Shaffer-Hartman-Somogyi method as described by Koch and Hauke (1935).

The data from the studies on the beef in Series II and III and on the swine were analyzed for variance by the method of Snedecor (1946).

TABLE 2. AVERAGE DRESSING PERCENTAGE, LIVER WEIGHT AND PERCENTAGE OF CARBOHYDRATE IN MUSCLE AND LIVER OF BEEF IN SERIES II

Number Animals	Sugar Fed	Dressing Yield	Liver Weights	Carbohydrate Calculated as Dextrose			
				Muscle	All Livers	Good Livers	Abnormal Livers
	lbs.	%	lbs.	%	%	%	%
5S	0	60.2±0.85[1]	12.2±0.48	0.19±0.01	1.66±0.14	1.88±0.18	1.46±0.16
5H	0	58.8±0.72	12.0±0.72	0.19±0.01	1.40±0.14	1.60±0.12	1.09±0.08
5S	6	61.6±0.54	15.8±0.30	0.17±0.02	1.92±0.28	2.16±0.30	1.54±0.52
5H	6	58.8±2.32	11.3±0.49	0.16±0.02	1.85±0.25	2.07±0.15	0.95±0.00
5S	12	57.1±0.57	16.4±0.87	0.20±0.02	2.04±0.10	2.18±0.09	1.82±0.04
5H	12	52.9±1.42	12.3±0.46	0.15±0.02	1.55±0.17	1.65±0.27	1.41±0.17

[1] Mean±standard error of the mean.

The beef muscle (9th to 11th ribs) was roasted at an oven temperature of 300° F. to an internal temperature of 175° F. and the pork loin at 350° F. to an internal temperature of 185° F. Shearing tests for tenderness were made on the cooked meat on the Warner-Bratzler shearing machine. A panel of 7 judges scored the cooked meat, using a scale of 1 to 7 with 7 being highest score, for tenderness, texture, juiciness, flavor of lean and of fat. A consumer acceptance test was made on the livers by a group of people who cooked the samples and judged them at home.

Results and Discussion

Experiments on beef

In Series I the feeding of sucrose 6 hours before slaughter resulted in the following: No increase in dressing percentage, a slight increase in the percentage of carbohydrate in the muscle and liver, similar pH

values for the muscle and liver, and no apparent correlation between quality appraisal tests and the amount of sugar fed.

The results of feeding sucrose 30 hours before slaughter in Series II is summarized in table 2. Feeding 6 pounds of sucrose slightly increased the dressing yield while feeding 12 pounds decreased it; these differences were highly significant. Differences in dressing yield between steers and heifers were significant. Liver weights showed significant increases for the sucrose-fed animals. Increases of one-tenth to one-third in the percentage of carbohydrate in the liver occurred with sucrose feeding, however, the differences were not significant. Carbohydrate values for the muscle were similar for the control and sucrose-fed animals.

TABLE 3. AVERAGE pH, COLOR READINGS AND QUALITY APPRAISAL TESTS ON BEEF IN SERIES II

Number Animals	Sugar Fed	pH		Color		Shear Force[1]	Tests by Panel of Judges		
		Muscle	Liver	Lean Ribeye	Exterior Fat		Tenderness[2]	Texture	Flavor of Lean
	lbs.					lbs.			
5S	0	5.9	5.4	3.2	2.2	8.8	6.0	5.6	6.1
5H	0	6.0	5.4	3.4	2.4	10.9	5.4	5.4	5.7
5S	6	5.9	5.4	3.2	2.2	10.7	5.2	5.3	5.7
5H	6	5.9	5.4	3.6	2.4	10.9	5.2	5.4	5.7
5S	12	6.0	5.4	3.6	2.4	9.7	5.9	5.6	6.0
5H	12	5.9	5.3	3.9	2.8	11.1	5.1	5.4	5.6

[1] Low score indicates meat is more tender.
[2] High score indicates meat is more tender.

Abscesses or flukes were found in thirty-six percent of the livers. Percentage carbohydrate values were consistently lower for the abnormal livers than for the normal livers, however, the abnormal livers weighed more (14.1 and 12.7 lbs. for the abnormal and normal livers, respectively).

Munsell color readings and pH values are presented in table 3. There were no apparent differences as a result of the sucrose feeding.

The scores for all lots of animals for the quality appraisal tests, that is, for the shearing tests and by the panel of judges were similar (table 3). Close agreement was noted between the scores for tenderness by the shearing machine and the panel of judges, the linear correlation being —0.942 which is highly significant.

The flavor and texture of the livers from sucrose-fed animals were preferred by 91 percent of the people (69) who tested them (55 and 36 percent for the livers from animals fed 6 and 12 lbs. of sucrose, respectively).

The results of feeding sucrose 3 to 12 days before slaughter in Series III are summarized in table 4. Feeding sucrose for 3 days increased the dressing yield by 0.7 to 1.7 percent. Although this increase was not as consistent for each of the other feeding periods, statistical analyses of data for the four feeding periods showed that the differences due to the number of feeding days and the quantity of sugar times time were highly significant. Liver weights increased from 0.4 to 1.9 pounds by feeding sucrose; these differences were significant.

Feeding sucrose for 3 or 6 days resulted in the highest percent of carbohydrate in the muscle and liver of the sugar-fed animals. Differ-

TABLE 4. AVERAGE DRESSING PERCENTAGE, LIVER WEIGHT AND PERCENTAGE OF CARBOHYDRATE IN MUSCLE AND LIVER OF BEEF IN SERIES III

Days Fed	Sucrose Fed	No. Animals	Dressing Yield	Warm Liver Weight	Carbohydrate Calculated as Dextrose		Shear Force
					Liver	Muscle	
	lbs.		%	lbs.	%	%	lbs.
0	0	20	59.4±0.26[1]	14.0±0.46	2.22±0.10	0.17±0.01	8.4±0.35
3	2	5	60.3±0.46	16.0±0.65	2.76±0.04	0.20±0.02	8.9±0.95
6	2	5	58.4±0.63	15.6±0.46	2.37±0.35	0.21±0.01	8.6±0.74
9	2	5	59.3±0.44	14.6±0.67	2.30±0.22	0.14±0.02	7.6±0.16
12	2	5	59.7±0.89	15.2±0.36	2.44±0.17	0.19±0.01	8.7±0.85
avg.	2	20	59.4±0.33	15.4±0.28	2.47±0.11	0.18±0.00	8.4±0.36
3	4	5	61.3±0.70	15.3±0.67	2.94±0.28	0.20±0.02	8.1±0.63
6	4	5	55.5±0.83	15.7±0.68	2.20±0.11	0.21±0.01	8.3±0.83
9	4	5	61.0±0.57	16.1±0.58	2.06±0.20	0.14±0.02	8.0±0.61
12	4	5	58.2±0.64	14.8±0.35	2.26±0.28	0.19±0.01	8.8±0.82
avg.	4	20	59.0±0.60	15.5±0.29	2.36±0.12	0.18±0.00	8.3±0.34

[1] Mean±Standard error of the mean.

ences in sugar content of the muscle and liver for the combined data for the four feeding periods were highly significant. Both time or number of days fed and amount of sugar fed significantly influenced the results. The abnormal livers (35 percent of the total) of this series as in Series II contained somewhat less carbohydrate than the normal livers (2.25 and 2.38 percent on the moist basis or 8.4 and 9.0 percent on the dry, fat-free basis for the abnormal and normal livers, respectively). The abnormal livers were also heavier (15.6 and 14.5 lbs.).

The sugar-fed animals tended to have lower pH values. Color of the fresh muscle was measured by the reflectance attachment of the Beckman spectrophotometer. The control group had the poorest color for the 3 day feeding period. However, this was not consistant for each of the other feeding periods. In general, the best color was shown in the muscles of beef fed 2 pounds of sucrose.

TABLE 5. AVERAGE DRESSING PERCENTAGE, LIVER AND HEART WEIGHT AND PERCENTAGE OF CARBOHYDRATE IN LIVER AND MUSCLE OF PORK

No. Animals	Sucrose Fed	Days Fed	Dressing Yield	Warm Liver Weight	Heart Weight	Carbohydrate Calculated as Dextrose		Shear Force
						Liver	Muscle	
	lbs.		%	lbs.	lbs.	%	%	lbs.
2	0	0	79.7±1.10[1]	3.2±0.71	0.7±0.00	0.80±0.28	0.18±0.01	15.4±0.80
3	0	0	73.1±1.79	3.0±0.04	0.5±0.41	0.90±0.26	0.18±0.04	7.0±0.84
Avg.			75.8±1.90	3.0±0.04	0.6±0.06	0.86±0.15	0.18±0.02	10.3±2.13
2	2	14	80.0±0.45	3.4±0.00	0.7±0.00	1.49±0.29	0.36±0.04	9.2±3.00
3	2	3	81.0±0.55	3.5±0.71	0.6±0.04	2.00±0.17	0.29±0.08	7.8±0.66
Avg.			80.4±0.04*	3.4±0.04	0.6±0.04	1.80±0.18**	0.32±0.05*	8.3±1.07
2	4	14	80.8±2.55	3.8±0.16	0.7±0.00	1.54±0.50	0.34±0.01	7.8±0.75

[1] Mean±Standard error of the mean.
* Significant $P<0.05$.
** Highly significant $P<0.01$.

Tenderness of the prime rib roast is shown by the shear force values in table 4. Differences for the combined feeding periods were not signficant. Quality scores by the panel of judges were also similar. Cooking losses tended to be slightly less in the roasts from beef fed 2 pounds of sucrose daily. Livers from sugar-fed animals were preferred for their flavor and texture by two-thirds of the people (75) testing them.

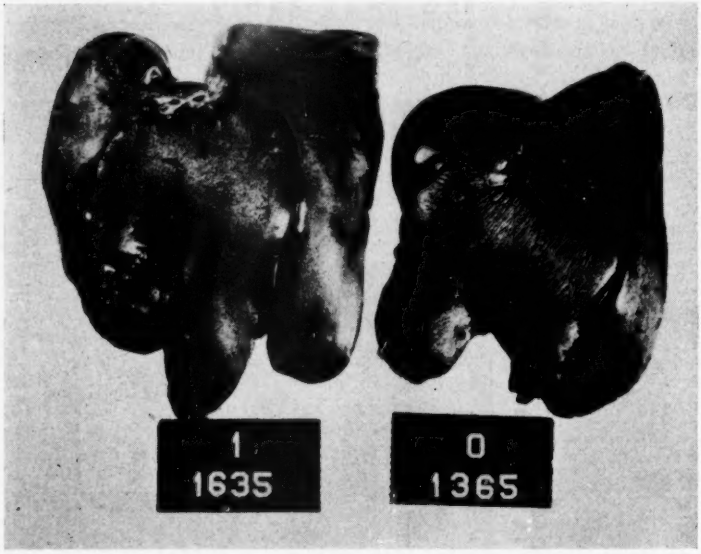


Figure 1. Pigs 0 and 1 were litter mates and were fed the same ration until 14 days prior to slaughter. Pig 1 was fed 2 pounds of surcose plus the basal ration while pig 0 was fed the basal ration without sugar. The liver of pig 0 weighed 1365 grams and the liver of pig 1 weighed 1635 grams.

These results indicate a need for further study before definite conclusions can be made as to the amount of sucrose which should be fed or length of feeding period. It should be noted, also, that all animals in Series III received sugar in the form of molasses, the controls as well as the lots fed 2 or 4 pounds of sucrose daily. Types of basal ration fed and handling procedure of animals or the ease with which animals are conditioned to eating the sucrose may influence greatly results obtained by sucrose feeding.

Experiments on swine

A summary of the findings on the sucrose-fed swine is presented in table 5. Sugar feeding increased the dressing yield by 4.6 percent which was statistically significant. Differences were also significant for the carbohydrate content of the muscle and highly significant for the liver carbohydrate values. The muscle of the sugar-fed animals contained almost twice as much sugar as those of the controls while the livers contained over twice the amount found in the controls. Liver and heart weights were increased (figure 1). Shear force differences were not quite significant. Quality appraisal tests showed that the sucrose-fed roasts had slightly better flavor and texture than the controls. The sucrose-fed livers were preferred for their flavor and texture.

Only slight changes occurred in the pH values as a result of sucrose feeding. Color readings were similar.

Summary

Sucrose in varying amounts was fed to 96 beef cattle and 12 swine from 6 hours to 14 days prior to slaughter. Under the conditions of these experiments, the following results were found:

1. Sucrose feeding, in general, resulted in slight increases in the dressing percentages, in carbohydrate content and in improvement in color and somewhat lower pH values of the fresh muscle. However, sugar-feeding at certain levels resulted in slight decreases in these characteristics.

2. The livers of the sucrose-fed animals were larger, contained more sugar, and had a better flavor and texture when cooked than those of animals fed without sucrose.

3. Quality appraisal scores by the panel of judges and shear force values were similar for all lots of beef. The sucrose-fed pork muscle was slightly more tender than the control.

Since there was a wide variation in response of animals and the number of animals per treatment was small, further study on larger numbers of animals is needed before definite conclusions can be established as to the optimum amount of sucrose which should be fed or length of feeding period.

Literature Cited

Bate-Smith, E. C. 1948. The physiology and chemistry of rigor mortis, with special reference to the aging of beef. Advances in Food Research 1:1.

Gibbons, N. E. and Dyson Rose. 1950. Effect of ante-mortem treatment of pigs on the quality of Wiltshire bacon. Canadian Jour. Res. 28:438.

Koch, F. C. and M. E. Hauke. 1948. Practical methods in biochemistry. Baltimore, Williams & Wilkins. p. 204.

Madsen, J. 1943. Researches into the keeping quality of pork after feeding sugar-containing foodstuffs. Nordisk Jordbrugsforskning. 5–6:340.

Ramsbottom, J. J., E. J. Czarnetsky, H. R. Kraybill, B. M. Shinn, B. M. Coombs, D. H. LaVoi and D. A. Greenwood. 1949. Dark cutting beef. Report published by National Livestock and Meat Board, Chicago.

Snedecor, G. W. 1946. Statistical Methods. 4th ed. The Collegiate Press, Inc., Ames, Iowa.

OCCURRENCE OF ESTRUS IN SOWS FOLLOWING PARTURITION[1]

L. N. Baker, H. L. Woehling,[2] L. E. Casida and R. H. Grummer

University of Wisconsin

ADVANCES in the field of baby pig nutrition, and the increases in numbers of commercial pig "hatcheries" have stimulated interest in the possibility of rebreeding sows soon after farrowing. Warnick, Casida and Grummer (1950) presented data on 36 sows checked for post-partum heat and killed at 10 days after parturition to determine the condition of their ovaries. Eighteen of the animals came into heat (all during the first week), but only two of the 18 had ovulated. None of the non-estrous sows had ovulated when killed 10 days post-partum. Another experiment by these workers failed to show that removal of the pigs at birth brought about ovulation during a 10 day post-partum interval; however, a greater follicular volume in non-suckling than in suckling sows was shown. It was suggested in the same report that the post-partum heat might be caused by an extra-ovarian source of estrogen and that such a source might be the afterbirth which is often eaten by the sow.

This is a report of a two-year study of the estrous behavior of sows following parturition. It was designed to evaluate the effect of sows eating their afterbirth and suckling for two days, on the interval from parturition to estrus, and to test the fertility of matings at first and second heat periods occurring within 21 days following parturition.

Experimental Procedure

None of the sows in the first year's study were allowed to eat the afterbirth or suckle their young. An especially designed farrowing crate was used in which the sows could not turn around and eat the afterbirth. The floor of the crate was elevated so that farrowed pigs were dropped to a lower level and hence they were unable to reach the sow. Heat checks were made daily with a boar starting on the day after farrowing and continuing until the sow either exhibited estrus or reached day–21 (day of farrowing considered day-zero). If a sow demonstrated a heat during the first 7 days after farrowing (below

[1] Published with the approval of the Director of the Agricultural Experiment Station Paper No. 508 from the Department of Genetics, University of Wisconsin, Madison, Wisconsin.

[2] Present address—Borden Company, Elgin, Illinois.

referred to as a post-partum heat), she was bred each day of heat and returned to the heat-check routine. (It was presumed from the work of Warnick, *et al.* (1950) that matings at a post-partum estrus would likely be infertile.) When a sow exhibited a heat 8 or more days after farrowing, she was bred each day of heat and slaughtered 24 hours after the end of estrus (slaughter delayed until 25 days after breeding in two cases). If a sow had not shown estrus on any of days–8 to –21, she was slaughtered. The observations made at the time of slaughter were the number of corpora lutea, number of fertilized ova, and the condition of the uteri.

In the second year's study the above plan was altered so that approximately two-thirds of the sows were allowed to eat the afterbirth and to suckle their young for two days (the health of the sows was not noticeably affected by the removal of their litters). Of those bred after 7 days post-partum, all were slaughtered 12 to 24 hours after the end of that heat. Also, the 8 to 21 day interval for the sows to show estrus before slaughter was changed to 8 to 31 days in the latter part of the second year's study.

Results and Discussion

The estrous behavior following parturition of 29 sows was observed during late winter and spring months (seven sows in 1951 and 22 in 1952). The effect of suckling for two days as compared to non-suckling was not statistically significant with respect to (1) the incidence of heats either during the first week or later, (2) the interval from farrowing to the onset of the heats, and (3) the length of these heats (table 1). These findings are in agreement with the studies of Warnick, *et al.* (1950) with one possible exception—they found a significantly greater length of estrus for the non-suckling than for the suckling sows in one group—their animals, however, suckled for a longer time. The combined data in table 1 show that approximately 59 percent of all sows exhibited a post-partum heat 1 to 3 days after farrowing and that the duration of the heats averaged 2.09 days. None of the sows conceived at their post-partum heat and examination of their ovaries when slaughtered about 1 to 3 weeks after that heat revealed no corpora lutea or corpora albicantia of a condition which might be attributed to that heat. Nearly 76 percent of all sows expressed a heat 8 to 16 days after farrowing. These heats lasted an average of 2.82 days, and 92.5 percent of the 197 recovered ova were fertilized.

The question arises as to where the line of demarcation can be drawn

TABLE 1. THE EFFECT OF SUCKLING UPON ESTRUS AND FERTILITY FOLLOWING PARTURITION

		Heat shown During First Seven Days (Post-partum heat)				Heat shown 8 to 21 Days				
									Ova Recovered	
Treatment	No. Sows	Incidence (%)	Interval from Parturition to heat (days)	Length (days)	Fertile Matings* %	Incidence (%)	Interval from Parturition to heat (days)	Length (days)	No.	% Fertilized
Suckling	14	57.1	2.25±0.25	1.94±0.33	0.0	85.7	12.25±0.48	2.71±0.12	142	96.5
Non-Suckling	15	60.0	2.00±0.24	2.20±0.21	0.0	66.7	11.10±0.66	2.95±0.39	55	85.7
Combined	29	58.6	2.12±0.17	2.09±0.19	0.0	75.9	11.73±0.41	2.82±0.18	197	92.5

* This estimate based upon either the return of the sows to heat and/or the absence of corpora lutea and embryos.

between ovulatory and anovulatory heats relative to the time of occurrence after parturition. In our data no anovulatory heats commenced later than day–3, and no ovulatory heats earlier than day–8. Warnick, *et al.* (19[illegible] on the other hand, found that out of nine non-suckling sows, two sows (which were two of three that gave birth to dead or very weak litters) had ovulatory heats—one commencing on day–4 (litter dead and resorbing at birth—gestation 124 days) and the other on day–7 (litter died immediately after birth). Two other sows in that study had anovulatory heats beginning on day–4. The sow that had an ovulatory heat beginning on day–4 was possibly in an endocrine state at the time of parturition in some respects equivalent to that ordinarily prevailing several days post-partum because of the prolonged gestation and the prenatal death of her litter; while the ovulatory heat on day–7 may well have been an expression of extreme but normal variation. Thus it appears that the line of demarcation may lie somewhere between day–4 and –7.

The average number of corpora lutea associated with an estrus 8 to 16 days after farrowing (table 2) was about the same for sows showing post-partum heats regardless of whether or not they were suckling (12.7 and 12.4, respectively); while for sows showing no post-partum heat, the average for those suckling was 14.4 and for the non-suckling sows 3.3. The disparity of the non-suckling-no-post-partum-heat group is further accentuated when it is pointed out that of the six sows in the group only two ovulated (one had cystic follicles and only one corpus luteum), one exhibited heat but had only cystic follicles, one had developing follicles, and the remaining two had inactive ovaries. It would appear that the two day suckling period and the post-partum heat, either or both, were more likely to lead to more complete ovarian function than was their absence. This was indicated by the lesser incidence of heat and ovulation at 8 to 16 days after farrowing in the non-suckling sows which did not express a post-partum heat.

Normally developing fetuses were found in the two sows allowed to carry their young for 25 days and 52 percent of their corpora lutea were represented by pigs thus giving an indication that the uterine environment at about two weeks after farrowing was suitable for placentation.

The maximum interval allowed before slaughter was changed from 21 to 31 days when it was noted that the first four of the seven sows which failed to exhibit an estrus on days–8 to –21 had many ovarian follicles ranging in size from 3 to 8 mm. It was surmised that an

TABLE 2. EFFECT OF SUCKLING AND OF POST-PARTUM HEAT ON THE OCCURRENCE OF HEAT AND ON THE NUMBER OF CORPORA LUTEA FORMED 8 TO 16 DAYS AFTER FARROWING

Experimental Group		Post-Partum Heat Shown			No Post-Partum Heat Shown		
		Heat 8–16 days After Farrowing		No heat 8–16 days After Farrowing	Heat 8–16 days After Farrowing		No heat 8–16 days After Farrowing
Suckling Sows	No. Sows	7		1	5		1[1]
	No. Ovulating	7		0	5		0
	Ave. No. Corpora Lutea Per Sow	12.7	(11.1)	0	14.4	(12.0)	0
Non-Suckling Sows	No. Sows	7		2	3[2]		3
	No. Ovulating	7		0			0
	Ave. No. Corpora Lutea Per Sow	12.4	(9.7)	0	3.3	(1.7)	0

Analysis of Variance (Number of corpora lutea formed in association with estrus 8–16 days after farrowing)

Source of Variation	d.f.	Mean Square
Suckling	1	66.81
Post-Partum Heat	1	158.55
Suckling x Post-Partum Heat	1	141.09**
Sows within subclasses	18	8.17

** $P \leq 0.01$.
[1] Partially Cystic.
[2] One animal partially cystic with one ovulation and one animal completely cystic.

extension of the interval might provide time for occurrence of heat and ovulation. Of the three sows which were allowed to go, however, two had inactive ovaries and the third was in a cystic condition at 31 days.

Summary

The occurrence and fertility of estrus during a 21-day period following parturition were studied in an experiment on 29 sows in which one group suckled their pigs for two days and were allowed to eat the afterbirth, and another group had their pigs removed at birth and were not allowed to eat the afterbirth. None of the post-partum heats (all occurring between the first and third day after farrowing) expressed by 17 sows were fertile—probably none of the sows ovulated. Twenty-two exhibited heat between day–8 and –16 and 21 ovulated with a fertilization rate on 197 eggs of 92.5 percent. The data suggest that neither suckling nor the post-partum heat had an over-all effect on the number of corpora lutea produced at the latter heats. However, six sows that neither suckled nor had post-partum heats had either inactive or cystic ovaries with few or no corpora lutea in five cases.

Literature Cited

Warnick, A. C., L. E. Casida and R. H. Grummer. 1950. The occurrence of estrus and ovulation in post-partum sows. JOURNAL OF ANIMAL SCIENCE 9:66.

HERITABILITY OF GAIN IN DIFFERENT GROWTH PERIODS IN SWINE[1]

CECIL T. BLUNN, GUY N. BAKER and L. E. HANSON[2]

University of Nebraska Agricultural Experiment Station

THE genetic and environmental correlations between growth rates of pigs at different ages were studied by Hazel, Baker, and Reinmiller at the North Platte Substation in 1943. Their results showed that heredity played a smaller, but more constant part in controlling gain than did environmental factors. Although several studies have reported heritability estimates of weights at different ages, gains do not seem to have been studied further. Consequently, it is not known whether the results of Hazel, *et al.* (1943) are generally applicable or not.

The object of the present work was to check the earlier work and to see whether the previous estimates would apply to animals of entirely different breeding.

Materials and Methods

Two sets of data were studied. The first came from inbred Duroc lines at the North Platte Substation. These lines were different from the lines studied by Hazel *et al.* (1943). The second set of data came from crosses involving four breeds started at Lincoln in 1946. These crosses involved the Duroc, Landrace, Berkshire, and Yorkshire breeds.

The North Platte data consisted of records on 2176 pigs farrowed in 450 litters sired by 105 boars. The pigs were farrowed in the 10 seasons from the fall of 1945 to the spring of 1950 inclusive and represented lines 8, 10, 11, and 12. The inbreeding of the dams averaged 18 percent and the offspring averaged 22 percent. Both gilt and sow litters were present in each season.

The Lincoln data were gathered in five seasons, spring and fall 1946, fall 1947, 1948, 1949, 1950. Records were secured on 572 pigs from 105 litters by 17 boars. The pigs were the result of two, three, and four breed crosses. All but three of the litters were from year old gilts. In the fall of 1947 three sows farrowed their first litter when they were 18 months old. None of the Lincoln pigs was inbred.

[1] Published with the approval of the director as paper No. 578. Journal series, Nebraska Agricultural Experiment Station in cooperation with the Regional Swine Breeding Laboratory, Ames, Iowa, Bureau of Animal Industry, U.S.D.A.

[2] Present address, Department Animal Husbandry, Univ. Minnesota.

Only those pigs which had recorded weights at the four ages, birth, 56 days (weaning), 112 days and 154 days, were used. From these weights the gains in the three periods birth to weaning (X_1), weaning to 112 days (X_2), 112 to 154 days (X_3) were obtained. The first two periods were 56 days long while the third period was only 42 days in length. The methods of analyzing the relationships between the gains as well as the factors making up the gains are those given by Hazel *et al.* (1943) with one modification. In the previous study the variance between the sires contained any line differences which were present in the North Platte herd whereas in the current study line differences were removed and differences between sires were on an intraseason intra-line basis. Consequently, the components of variance and covariance as well as estimation of the genetic and environmental variance and covariance were calculated by the method developed by Dickerson (1944 and 1947).

Results

The analyses of variance and covariance for both the North Platte and Lincoln data are presented in table 1. The table shows that for both North Platte and Lincoln, differences between litters by the same sire were larger than differences betwen individuals of the same litter in all cases.

Differences between sires were present in both the North Platte and Lincoln data. These differences were significant for all three periods in the North Platte data. In the Lincoln data, sire differences were not significant for gain in the first period and significant only at the five percent level for the second period and third period. Although for the purposes of this study, line and seasonal differences were of minor importance, it is interesting to note that seasonal differences were significant for all three periods at North Platte, but only for the first period at Lincoln. Line differences in the North Platte data were not significant for the first period.

The covariances were tested for significance by determining the correlations for each row of table 1. The correlations between litters by the same sire were significant for both the North Platte and Lincoln data for the three combinations of gains. In the North Platte data the correlation between sires within lines was significant for gain in periods 1–2, but not for the other two combinations of periods. In the Lincoln data the correlation between sires in seasons was significant for gain in periods 2–3, but not for gain in periods 1–2, or gain in periods 1–3.

TABLE 1. ANALYSES OF VARIANCE AND COVARIANCE FOR GAINS IN THE THREE PERIODS

Source	DF	Mean Squares X_1	X_2	X_3	Covariances X_1X_2	X_1X_3	X_2X_3	Components of Variance[1]
				North Platte				
Total	2175							
Seasons	9	1036.9	17001.6	18283.8	964.6	482.8	−2797.0	
Lines in Seasons	28	218.2	1117.4	1888.3	202.5	264.1	419.0	
Sires in Lines	67	166.5	631.3	614.0	189.0	41.6	242.0	$P^2 + k'M^2 + k''S^2$
Litters by Same Sire	345	109.5	306.2	394.6	76.2	51.7	107.8	$P^2 + k\,M^2$
Within Litters	1726	61.1	109.8	182.0	21.1	6.6	41.2	P^2
				Lincoln				
Total	571							
Seasons	4	937.4	2293.2	940.8	1438.1	−619.2	−1094.8	
Sires in Seasons	16	117.6	1172.5	735.7	104.8	98.0	648.1	
Litters by Same Sire	84	105.9	552.2	312.3	123.8	51.2	200.1	
Within Litters	467	22.2	173.1	143.7	22.4	11.0	81.3	

[1] For North Platte: k=4.72; k′=5.01; k″=17.25.
For Lincoln: k=5.36; k′=5.72; k″=25.22.

TABLE 2. COMPONENTS OF VARIANCE AND COVARIANCE ATTRIBUTED TO DIFFERENCES BETWEEN SIRES (S), LITTERS BY SAME SIRE (M), AND BETWEEN LITTER MATES (P)

Period	V(S)	V(M)	V(P)	Period Combinations	Cov. (SS)	Cov. (MM)	Cov. (PP)
			North Platte				
1	3.13	10.26	61.12	1:2	6.34	11.68	21.08
2	18.15	41.60	109.81	1:3	—0.75	9.54	6.66
3	11.96	45.03	182.01	2:3	7.54	14.10	41.25
			Lincoln				
1	0.24	15.63	22.15	1:2	—1.02	18.92	22.43
2	23.59	70.73	173.08	1:3	1.74	7.51	11.00
3	16.34	31.44	143.73	2:3	17.45	22.18	81.27

The components of the mean squares and mean products are given in table 2. In this table the number of pigs per litter and the number of litters per sire were determined according to the formulas developed by Dickerson (see Hetzer, Dickerson, and Zeller, 1944). Two of the components are negative, but this may be due to sampling errors since they are determined from covariance terms which were not statistically significant. On the other hand, they may be real and have a sound biological explanation. The explanation of these figures will be discussed later.

TABLE 3. GENOTYPIC AND ENVIRONMENTAL VARIANCES AND COVARIANCES FOR THE THREE PERIODS

		North Platte			Lincoln		
		Period			Period		
Source	Period	1	2	3	1	2	3
Genotype	G_1	16.90	34.24	—4.05	0.96	—4.08	6.96
	G_2		98.01	40.72		94.36	69.80
	G_3			64.58			65.36
Litter Environment	L_1	8.20	6.14	11.83	15.39	19.94	5.77
	L_2		26.97	7.54		47.14	4.73
	L_3			38.03			15.10
Individual Environment	E_1	53.48	5.61	8.49	21.67	24.47	7.52
	E_2		65.52	22.85		125.90	46.37
	E_3			152.83			111.05
Phenotype	X_1	78.58	45.99	16.27	38.02	40.33	20.25
	X_2		190.50	71.11		267.40	120.90
	X_3			255.44			191.51

The genetic and environmental variances and covariances are given in table 3. In this table V(G) is the additive genetic variance. V(L) is the variance due to the dam's influence. This may be partly genetic in nature, but it is not due to the pigs own genes, and affects all members of a litter alike. Dickerson (1947) breaks this portion of the variance into two portions V(Gm), the strictly genetic portion and V(Em), the environmental portion. Such a division was not possible in the present data. V(E) is the environmental variance peculiar to each individual pig. V(X) is the phenotypic variance and equals V(G)+V(L)+V(E). The covariance terms are completely analogous to the variance terms in this and the following discussion.

The North Platte data are based on partially inbred lines, hence the distribution of the genetic and environmental variances and covariances will not be the same as those in a random bred population. The variances and covariances were adjusted by the method given by Dickerson (1947) for the inbreeding which has taken place. The value of f', the average inbreeding of the dams, was 0.18 and the value of f, the average inbreeding of the pigs, was 0.22. The components of the mean squares are composed of the following portions of genetic and environmental variance:

$$V(P)=\frac{(1-f')}{2}\,V(G)+V(E)=0.41\,V(G)+V(E)$$

$$V(M)=\frac{1+f'-2f}{4}\,[V(G)+4V(Gm)]+V(Em)$$

$$=0.185\,[V(G)+4V(Gm)]+V(Em)$$

$$V(S)=\frac{1+f'-2f}{4}\,V(G)=0.185\,V(G)$$

$$V(X)=(1-f\,[V(G)+V(Gm)]+V(Em)+V(E)$$

$$=0.78\,[V(G)+V(Gm)]+V(Em)+V(E)$$

These give the following equations which were used to calculate the values in table 3:

$$V(G)=5.40\,V(S)$$
$$V(L)=1.15\,[V(M)-V(S)]$$
$$V(E)=V(P)-2.44\,V(S)$$
$$V(X)=V(G)+V(L)+V(E).$$

The Lincoln data are from a herd where breed crosses were being made so no inbreeding occurred. The distribution of the genetic and environmental portions of variance among the three components of variance was assumed to be as follows:

$$V(G)=4V(S)$$
$$V(L)=V(M)-V(S)$$
$$V(E)=V(P)-2V(S)$$
$$V(X)=V(G)+V(L)+V(E)$$

In table 3 the first figure in each row for North Platte or Lincoln is the variance, while the remaining figures are the covariance terms. North Platte shows a negative genetic covariance between gain in period 1 and period 3, while Lincoln shows a negative genetic covariance between gain 1 and gain 2. These, of course, lead to the negative genetic correlations which are shown in figure 1 and table 4.

These negative covariance terms may have been caused by one or more of the following reasons. In the Lincoln data, for instance, severe outbreaks of necrotic enteritis occurred shortly after weaning in two of the years. Also, two different management practices were followed in the Lincoln herd. As a result of these two events different sets of genes might have been operating in the two growth periods. At North Platte distinct season differences were found. In the spring the pigs were raised on pasture, whereas in the late fall and winter months no green feed was available. These differences might have been large enough to call into play different sets of growth genes in the preweaning and late post-weaning periods.

Conner (1923) has pointed out that interpretation of correlations in population data can be misleading because of the placement of the frequency distributions of the groups making up the population. It is possible to have positive correlations between characters in the separate groups and yet have a negative correlation when all groups are considered. This may have occurred in the Lincoln and North Platte data through the non-randomness of errors when the several periods were pooled.

Then too, if total growth in swine is limited, dividing the growth period into several arbitrary periods and computing the genetic correlations between them would automatically induce negative genetic correlations between some of the periods. If there were a compensating growth mechanism operating, a negative genetic correlation would also be found.

Figure 1 is a graphic presentation of the genetic and environmental factors causing variation in the observed phenotypic values. The correlations, represented by curved double headed arrows, give the relations between the several factors. The paths, represented by straight lines,

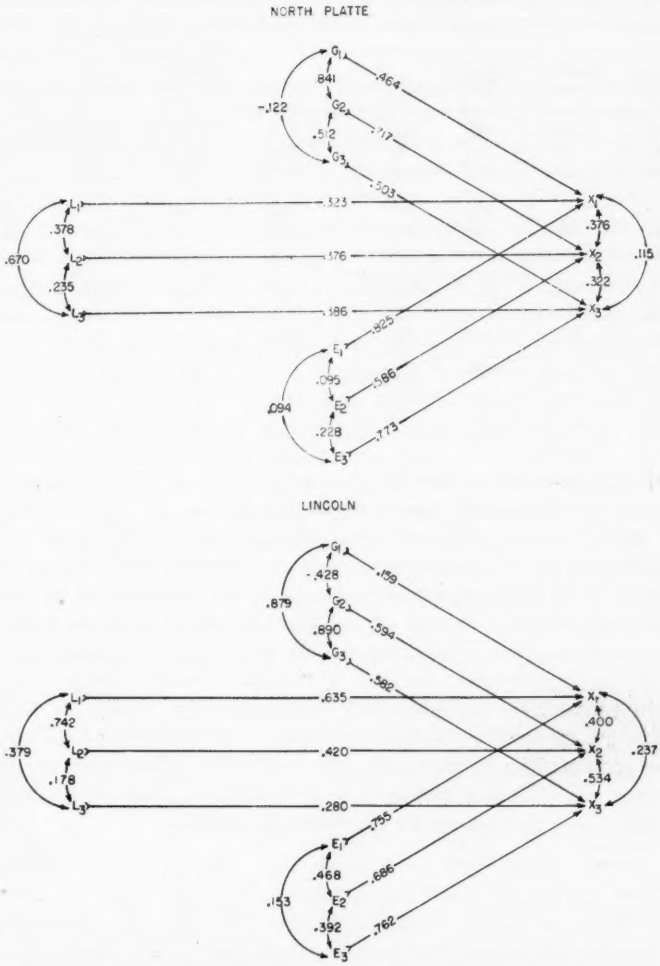


Figure 1. Path coefficient diagram of the genetic and environmental relations underlying the observed correlations between gain in the three periods for North Platte (top) and Lincoln data (bottom). X_1, X_2, X_3=gain in the three periods. G_1, G_2, G_3=genotype for gain in the three periods. L_1, L_2, L_3=litter effects for three periods. E_1, E_2, E_3=individual pig environment plus dominance and epistatic deviations. The straight lines represent path coefficients and the curved lines represent correlation coefficients.

TABLE 4. CORRELATION AND PATH COEFFICIENTS FOR GAINS IN THE THREE PERIODS

Correlations	Hazel *et al.* (1943)	North Platte	Lincoln	Paths	Hazel *et al.* (1943)	North Platte	Lincoln
G_1G_2	.708	.841	—.428	X_1G_1	.387	.464	.159
G_1G_3	.454	—.122	.879	X_2G_2	.531	.717	.594
G_2G_3	.701	.512	.890	X_3G_3	.407	.503	.582
L_1L_2	.541	.378	.742	X_1L_1	.689	.323	.635
L_1L_3	.256	.670	.379	X_2L_2	.515	.376	.420
L_2L_3	.192	.235	.178	X_3L_3	.474	.386	.280
E_1E_2	.306	.095	.468	X_1E_1	.613	.825	.755
E_1E_3	.019	.094	.153	X_2E_2	.673	.586	.686
E_2E_3	.663	.228	.392	X_3E_3	.781	.773	.762
X_1X_2	.440	.376	.400				
X_1X_3	.164	.115	.237				
X_2X_3	.547	.322	.534				

give the quantitative importance of each factor in causing variation. The values given in the figure were calculated from the data in table 3. In table 4 the correlation and path coefficients calculated by Hazel *et al.* (1943) and for the current sets of data are given for ready comparison. Except for the two negative genetic correlations the values are not very different, especially in view of the large sampling errors involved in studies of this kind. The values for the paths vary somewhat also.

Heritability estimates for gain in the three periods can be arrived at by squaring the individual path coefficients G_1X_1, G_2X_2, and G_3X_3. These are the coefficients of determination or the amount of total variation accounted for by each path. The heritability estimates for the two current sets of data as well as those determined by Hazel *et al.* (1943) together with the average for the three are as follows:

Period	North Platte	Lincoln	Hazel *et al.*	Average
1	.22	.02	.15	.13
2	.51	.35	.28	.38
3	.25	.34	.17	.25

The average for period 3 is not strictly valid for the estimates are not exactly comparable. The one calculated by Hazel *et al.* was for gain made during a period 56 days long while the two current estimates are for a gain period of 42 days. The difference in length of period may be one reason why the two current estimates are higher than that found by Hazel *et al.* Environmental effects would be larger in the earlier

estimate for there were 14 more days involved and the added days occur at the time environment is becoming increasingly important. (See Baker *et al.* (1943)).

In some instances the current values are higher than those found by Hazel *et al.* and in other instances they are lower. The average for the three sets of values shows that gain from weaning to 112 days is 13 and 25 percent more heritable than is gain from 112 days to 154 days or from birth to weaning respectively.

Nordskog *et al.* (1944) calculated the heritability of gain in successive 28-day intervals from weaning to 168 days using paternal half-sib relationships. The estimates were .18, .26, .28, .24 for the periods 56–84, 84–112, 112–140, and 140–168 day intervals. The estimate of heritability of gain from 56–112 days of age was .28. This is in agreement with the value found by Hazel and co-workers. It is difficult to compare the results of the present study with those of Nordskog and associates for the periods studied were in general quite different. In general it is felt that there is fair agreement between the two sets of estimates.

Gain over an arbitrary period of time may be of value in determining the optimum time for selecting replacement animals. The producer, however, is interested in the heritability of total gain for he sells or keeps the sum of the gains when his animals go to market or are retained for breeding. The correlation between genotype and gain should provide a measure of the genetic value of the animals. The correlations between G_T and X_i as well as the multiple correlation, $R_{G_T.X_1X_2X_3}$ are:

	North Platte	Lincoln	Hazel *et al.*	Average
$r_{G_TX_1}$	.302	.036	.284	.207
$r_{G_TX_2}$	.699	.560	.498	.586
$r_{G_TX_3}$	.353	.587	.361	.437
$r_{G_TX_T}$	.637	.597	.497	.577
$R_{G_TX_1X_2X_3}$	.754	.690	.516	.653

The two sets of correlations based on North Platte data show a remarkable agreement. The current values are higher in all but one case, but the order of importance is the same in both sets of figures. The Lincoln results do not agree with those obtained at North Platte. The size of the correlation coefficients is, in most instances, intermediate between the two values for North Platte. The order of importance, however, is quite different. Even though the heritability of gain in period 2, the period from weaning to 112 days of age, is slightly higher than the heritability of gain in period 3 the correlation between total geno-

type and gain in period 2 is next to the smallest of the five correlations.

Lincoln data from three seasons, fall 1947, 1948, 1949 were used to calculate the intra-sire offspring on dam regression of gain in the same three periods used above.

A total of 446 pigs were produced by 86 sows. The litters were by 17 sires. Each dam was represented as many times as she had pigs in a litter. Based on these data, heritability of gain was estimated by doubling the regression coefficient. The heritability estimates thus obtained are: period 1=.11, period 2=.28, and period 3=.08.

Here again, heritability of gain in period 2 was higher than it was for the other two periods. Heritability in period 3 was much lower than was found from the paternal half-sib relations, but the sampling errors are probably very large because of the small number of dams which were used. The heritability estimates of Nordskog *et al.* (1944) based on intra-sire offspring-dam regressions were all much lower than those determined from paternal half-sib relations.

The results of the current study substantiate the findings of Hazel *et al.* (1943) and emphasize the statements made concerning the selection of boars. If growth rate is one of the criteria on which animals are selected, preweaning gain, as measured by weaning weight, is not a very reliable measure of the hereditary growth rate (average $r_{G_T X_1}$= .207). On the other hand, gain from 56 to 112 days of age is a slightly better index of hereditary growth rate (average $r_{G_T X_2}$=.586) than is gain from 112 to 154 days (average $r_{G_T X_3}$=.437) or gain from birth to 154 days (average $r_{G_T X_T}$=.577).

Then too, gain from 56 to 112 days is measured before puberty and is not influenced by the onset of ranting in the boars which is often accompanied by a temporary loss in weight. During the early post weaning growth period the animals are growing rapidly. This growth is largely in bone and muscle rather than fat (McMeekan, 1940). Thus, as pointed out by Dickerson (1947), selection at some point near 112 days of age should emphasize leanness, particularly if it is used in conjunction with selection for good milking ability and high sow productivity in the dams.

Some unpublished work based on Lincoln data shows that 112-day weight can be used satisfactorily in selecting boars. The animals were ranked using 112-day weight in the selection index and then again using the 154-day weight. The correlation between the two rankings of the animals was +.91. This means that if a preliminary selection were made at 112 days of age and double the number of boars finally

desired were saved the remaining boars could be castrated without fear of discarding the top individuals. It was also found that boars castrated at 112 days of age could be marketed satisfactorily by the time they reached market weight, which they did at the same time as the rest of the stock.

Summary

Data from 2176 pigs produced at North Platte and 572 pigs produced at Lincoln were used to determine the heritability of gain in three growth periods. The growth periods studied were (1) birth to weaning (56 days), (2) 56 to 112 days, and (3) 112 to 154 days. Heritability of gain was based on paternal half-sib relationships.

Heritability estimates of gain in the three periods were for North Platte .22, .51 and .25 respectively and for Lincoln .02, .35 and .34 respectively. These estimates agree quite well with those found by Hazel *et al.* (1943) based on earlier North Platte stock considering the large sampling errors to which estimates of this kind are subject. The three sets of estimates show that gain in the period 56 to 112 days is determined more by the pig's own genes than is gain in either the preceding or following period.

Based on the intra-sire regression of offspring on dam heritability estimates of gain were .11, .28, and .08 for the three periods respectively.

The multiple regression based on growth in each period was .754 for North Platte and .690 for Lincoln. With respect to selecting boars for use in a breeding program the increased accuracy of the multiple regression is offset by the added time which must elapse before the selection can be made.

The present data substantiate the findings and statements of Hazel *et al.* (1943) concerning the selection of boars.

If growth rate is one of the criteria upon which selections are based, gain from 56 to 112 days of age can be used satisfactorily. It has the advantage of being available relatively early and it is based more upon growth in bone and muscle and less on fatness than is gain at a later period.

Literature Cited

Baker, M. L., L. N. Hazel, and C. F. Reinmiller. 1943. The relative importance of heredity and environment in the growth of pigs at different ages. JOURNAL OF ANIMAL SCIENCE 2:1.

Conner, A. B. 1923. The interpretation of correlation data. Texas Agr. Expt. Sta. Bul. 310:1.

Dickerson, G. E. 1947. Composition of hog carcasses as influenced by heritable differences in rate and economy of gain. Iowa Agr. Expt. Sta. Res. Bul. 354: 492.

Hazel, L. N., M. L. Baker, and C. F. Reinmiller. 1943. Genetic and environmental correlations between the growth rates of pigs at different ages. JOURNAL OF ANIMAL SCIENCE 2:118.

Hetzer, H. O., G. E. Dickerson, and J. H. Zeller. 1944. Heritability of type in Poland China swine as evaluated by scoring. JOURNAL OF ANIMAL SCIENCE 3:390.

McMEEKAN, C. P. 1940. Growth and development in the pig, with special reference to carcass quality characters. Jour. Agr. Sci. 30:276; 387; 511.

Nordskog, A. W., R. E. Comstock, and L. M. Winters. 1944. Hereditary and environmental factors affecting growth rate in swine. JOURNAL OF ANIMAL SCIENCE 3:257.

EFFECTS OF CERTAIN ANTIBIOTICS AND VITAMIN B_{12} ON PANTOTHENIC ACID REQUIREMENTS OF GROWING-FATTENING SWINE[1, 2]

DAMON V. CATRON, ROBERT W. BENNISON, HELEN M. MADDOCK, GORDON C. ASHTON and PAUL G. HOMEYER

Iowa Agricultural Experiment Station

SUPPLEE *et al.* (1942) showed that the pantothenic acid requirements of the pig depend on several factors, including stage of development, previous nutritional history and interrelationships with other nutrients.

Rations of natural feedstuffs were found by McMillen *et al.* (1948) to be low or borderline in pantothenic acid for maximum growth of pigs. Luecke *et al.* (1949 and 1950) produced characteristic pantothenic acid deficiencies with both semi-synthetic and natural rations containing 3.4, 3.8 and 4.2 mg. of pantothenic acid per pound of ration in the absence of added vitamin B_{12} and antibiotics.

Vohs *et al.* (1950) found that 5 mcg. vitamin B_{12} per pound of corn-soybean oil meal ration were adequate for optimum growth in growing-fattening swine. Using crystalline vitamin B_{12}, Richardson *et al.* (1951) reported the vitamin B_{12} requirements of young growing pigs to be 5 mcg. or less in the presence of antibiotics (40 mg. per pound of ration). They observed an interaction between antibiotics and vitamin B_{12}.

Yacowitz *et al.* (1950), working with chicks, found that vitamin B_{12} and pantothenic acid spared each other. Evans *et al.* (1951) found that in the absence of sufficient vitamin B_{12}, pantothenic acid accumulates in the liver; indicating that vitamin B_{12} aids in the transfer of pantothenic acid from the liver for use elsewhere in the chick's body.

Antibiotics have been found to increase rate of gain by various workers including Lepley *et al.* (1950), Catron *et al.* (1951), Speer *et al.* (1951) and Luecke *et al.* (1951). Swick *et al.* (1951) showed aureomycin and streptomycin to be superior to other antibiotics for increasing growth in pantothenic acid deficient rats.

[1] This work was supported in part by a grant from Merck & Co., Inc., Rahway, N. J. The streptomycin, penicillin and all vitamins except A, D_2 and folic acid were supplied by Merck & Co., Inc. Vitamin D_2 was supplied by Standard Brands, Inc., N. Y., N.Y.; the aureomycin and folic acid by Lederle Laboratories, Pearl River, N. Y. and the terramycin by Chas. Pfizer & Co., Inc., Brooklyn, N. Y. The authors are indebted to Dr. R. W. Luecke for the pantothenic acid assays of the experimental rations (experiment I), to Prof. E. A. Kline of the Meat Laboratory for help in collecting the carcass data, and to Mr. Don Quinn and his associates at the swine nutrition farm for their assistance.

[2] Journal paper no. J-2075 of the Iowa Agricultural Experiment Station, Animal Husbandry Department, Ames, Iowa. Project no. 930.

Biely and March (1951) found aureomycin to exert a "sparing-like" effect on various B-vitamins other than pantothenic acid. Similar "sparing-like" effects of aureomycin on vitamin B_{12} were noted in rats by Cravioto-Munzo and co-workers (1951), while Davis and Chow (1951) demonstrated an increase in the vitamin B_{12} content of fecal material with the addition of aureomycin to the diet.

The two experiments reported herein were conducted to determine the effects of supplementing an all-plant protein ration with antibiotics and vitamin B_{12} on the pantothenic acid requirements of growing-fattening swine in concrete dry lot.

TABLE 1. COMPOSITION OF BASAL RATIONS

Experiment No.	I	II
Protein in Ration (%)	18	14
Ingredients	%	%
Ground Yellow Corn	69.0	80.0
Solvent Soybean Oil Meal (Blended)	26.2	15.0
Special Steamed Bone Meal	2.7	2.5
Calcium Carbonate	0.5	0.9
Vitamin Premix	1.0[1]	1.0[2]
Iodized Salt	0.5	0.5
Trace Mineral Mix[3]	0.1	0.1

[1] Contributed the following vitamins per lb. of total ration: α-tocopherol, 1.5 mg.; biotin, 0.2 mg.; choline chloride, 250 mg.; folic acid, 0.5 mg.; inositol, 200 mg.; niacin, 10 mg.; p-amino benzoic acid, 0.5 mg.; pyricin, 1.0 mg.; pyridoxine, HCl 1.5 mg.; riboflavin, 1.0 mg.; thiamin, HCl 1.5 mg.; vitamin B_{12}, 10 mcg.; menadione 0.5 mg.; vitamin A, 300 I.U.; and vitamin D_2, 400 I.U.

[2] Contributed the following vitamins per lb. of total ration: riboflavin, 1 mg.; niacin, 5 mg.; choline chloride, 100 mg.; vitamin A, 100 I.U. and vitamin D_2, 400 I.U.

[3] Contributed 26.5 mg. Mn; 31.5 mg. Fe; 2.16 mg. Cu; 0.72 mg. Co; 2.025 mg. Zn; and 63.9 mg. Ca per pound of total ration.

Plan and Procedure

Experiment I

A replicated 2 x 5 factorial experiment with a split-plot design was used. Eighty weanling pigs consisting of 40 purebred Durocs and 40 Landrace x Duroc crossbred pigs were allotted from outcome groups (litters) into 20 lots of four pigs each. Prior to placement on experimental rations all pigs were wormed with sodium fluoride and sprayed with benzene hexachloride. They were housed inside on concrete and bedded with wood shavings.

The control lots of pigs received the basal ration shown in table 1. The basal ration was calculated to contain 4.1 mg. pantothenic acid

per pound of ration based on values of 2.8 mg. and 8.1 mg. per pound for corn and soybean oil meal respectively. The other treatments consisted of the basal ration plus 1, 2, 3 and 4 mg. of pantothenic acid per pound of total ration added in the form of calcium pantothenate. Each of the five pantothenic acid levels was fed to four lots of pigs. Two of the four lots of pigs on each pantothenic acid level received antibiotics. The antibiotic mixture was composed of 10 mg. each of aureomycin hydrochloride, terramycin hydrochloride, streptomycin sulfate and procaine penicillin G added per pound of total ration.

All rations contained 18 percent protein from the starting weight (41) to 75 pounds, 15 percent from 75 to 150 pounds, and 12 percent from 150 to 200 pounds. The protein levels were attained by substituting corn for soybean oil meal. The quantity of calcium pantothenate was adjusted for each protein level to maintain the starting pantothenic acid levels. A vitamin premix containing 15 vitamins was included in the rations (table 1).

Ration samples were assayed microbiologically for pantothenic acid according to the method of Buskirk *et al.* (1948). The rations without the antibiotics assayed 3.71, 4.86, 5.78, 6.89 and 7.77 mg. of pantothenic acid per pound for the respective pantothenic acid-level rations.

All pigs were fed and watered *ad libitum*. The live weights and feed consumption were determined bi-weekly. Each animal was removed from experiment individually as it reached 200 pounds. Five barrows of each breeding receiving antibiotics and a like number receiving rations without antibiotics, selected without respect to pantothenic acid levels, were slaughtered for carcass studies when removed from experiment. Body length, thickness of back fat, and moisture content of liver and loin were measured.

Experiment II

Sixty-four Landrace x Duroc crossbred pigs with similar previous nutritional history were randomly alloted within sexes to 16 pens of four pigs each. The management practices were essentially the same as in the first experiment.

This experiment was a replicated 2 x 2 x 2 factorial with 0 and 10 mg. of aureomycin, 3.5 and 7.0 mg. of pantothenic acid, and 0 and 10 mcg. of vitamin B_{12} per pound of ration. This permitted a study of the interaction of the antibiotics and vitamins in question. The protein content of the ration shown in table 1 was 14 percent for the entire experimental period of 10 weeks. The pigs weighed an average of 32

pounds at the start of this experiment compared to an average of 41 pounds in the previous experiment. The vitamin premix included only vitamins A, D_2, riboflavin, niacin and choline. The number of vitamins added was restricted in an effort to confine possible sparing effects on pantothenic acid to antibiotics and vitamin B_{12}. According to microbiological assay, the basal ration contained 3.7 mg. of pantothenic acid per pound and the ration with added pantothenic acid contained 7.0 mg. per pound.

TABLE 2. SUMMARY OF GROWTH AND FEED DATA FOR EXPERIMENT I[1] (WINTER 1950–51)

	Pantothenic Acid Added to Basal Ration (milligrams per pound)					
Antibiotics	0	1	2	3	4	Average
	Average Daily Gains (lb.)[2]					
No Antibiotics	1.62	1.65	1.61	1.64	1.68	1.64
Antibiotics	1.87	1.91	1.92	1.88	1.90	1.89
Average	1.74	1.78	1.76	1.76	1.79	
	Average Daily Feed (lb.)					
No Antibiotics	6.63	6.28	6.20	6.39	6.28	6.36
Antibiotics	6.93	6.66	7.13	6.53	7.62	6.97
Average	6.78	6.47	6.66	6.46	6.95	
	Feed Consumed Per 100 Pounds Gain (lb.)					
No Antibiotics	412	385	390	396	390	394
Antibiotics	372	352	376	352	407	372
Average	392	368	383	374	398	

[1] Two lots of four pigs each per treatment.
[2] Average initial weight per pig: no antibiotics 41.6 lb., antibiotics 40.0 lb. Final weight of pigs approximately 200 lbs.

Results and Discussion

Experiment I

The daily gains of the pigs in the first experiment, presented in table 2, show no significant differences among levels of pantothenic acid regardless of whether antibiotics were included in the rations. The pigs receiving antibiotics gained 0.25 pound more per day than the pigs not receiving antibiotics. This difference was not statistically significant (refer to table 3) since a split-plot design was used to increase the efficiency in estimating the effects of different pantothenic acid levels and the interaction of pantothenic acid with the antibiotic, at the expense of decreasing the precision of estimating the effect of the anti-

biotic. However, similar increases in gains which were statistically significant have been obtained by the addition of aureomycin in other experiments at this station.

Since no pantothenic acid deficiencies developed, the results may at first seem to be in disagreement with Luecke (1950) who produced deficiencies on 4.2 mg. pantothenic acid per pound. This may be explained in part by the difference in initial age and size of pigs, and

TABLE 3. ANALYSES OF VARIANCE OF AVERAGE DAILY GAINS FOR EXPERIMENTS I AND II

Source of Variation	d.f.	Mean Square	
	Experiment I[1]		
Replications	1	0.1639	
Antibiotics	1	1.2890	21.33
Experimental Error (a)	1	0.0604	
Pantothenic Acid (PA)	4	0.0050	0.40
PA x Antibiotics	4	0.0041	0.30
Experimental Error (b)	8	0.0140	
Pigs of same breed within pens	40	0.0276	
	Experiment II		
Replications	1	0.0276	
Antibiotics	1	1.3308	121.07**
Vitamin B_{12} (B_{12})	1	0.0090	
Pantothenic Acid (PA)	1	0.0241	2.19
Antibiotic x B_{12}	1	0.0047	
Antibiotic x PA	1	0.0131	1.19
B_{12} x PA	1	0.0420	3.82
Antibiotic x B_{12} x PA	1	0.0776	7.06*
Experimental Error	7	0.0110	
Pigs within Pens	48	0.0721	

* Significant at P=0.05.
** Significant at P=0.01.
[1] Breed effects not considered.

the difference in ration fortification. The pigs in this experiment were two weeks older and weighed approximately 16 pounds more at the start of the experiment than those used by Luecke. These rations were also well fortified with vitamin B_{12} and contained 2 units percent more protein. This would seem to confirm the probable variation in pantothenic acid requirements depending on age, weight, condition and ration as suggested by Supplee (1942). It was also thought that the added vitamin B_{12} might have a sparing effect on pantothenic acid in pigs as reported by Yacowitz *et al.* (1950) in chicks.

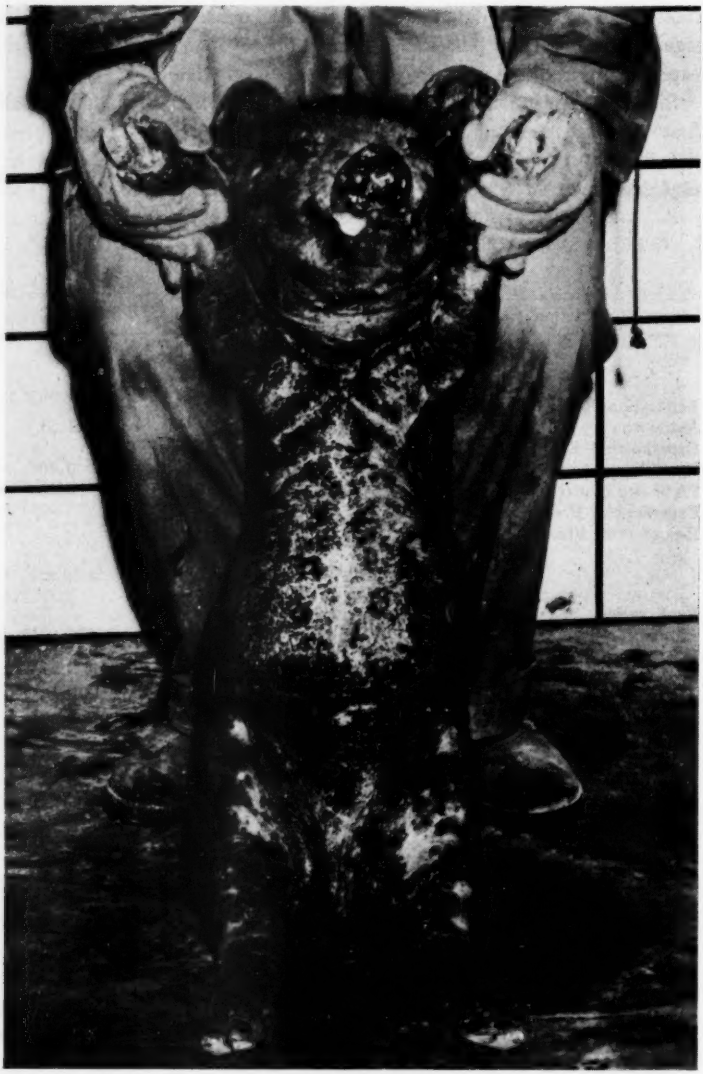


Figure 1. Pig receiving 6 mg. pantothenic acid without antibiotics, showing a severe dermatosis.

Antibiotic feeding prevented the looseness observed in the non-antibiotic fed pigs during the first two weeks on experiment. Influenza, which temporarily affected the pigs on all ration treatments, was less severe in the antibiotic-fed pigs and recovery was more rapid. One pig on the 6-mg. level of pantothenic acid without antibiotics developed a severe dermatosis as shown in figure 1. This condition became so severe at the joints that the pig was unable to walk. Following a four day therapeutic treatment with aureomycin, the pig slowly recovered until by market weight scarcely any sign of the abnormality was evident.

TABLE 4. CARCASS MEASUREMENTS FOR EXPERIMENT I[1]

Treatment and breed	Body Length (Inches)	Back Fat[2] (Inches)	Percent Moisture[3]	
			Liver	Loin
No Antibiotics				
Duroc	28.2	1.82	71.6	72.7
Landrace x Duroc	29.5	1.64	70.6	73.7
Average	28.4	1.73	71.1	73.2
Antibiotics				
Duroc	28.1	1.92	72.1	72.7
Landrace x Duroc	29.7	1.62	71.7	72.9
Average	28.9	1.77	71.9	72.8

[1] Each figure represents an average of 5 animals.
[2] Average of four measurements taken at first, seventh and last rib and last lumbar of each pig.
[3] Average of two determinations for each tissue on each animal.

Measurement of the water consumption during the eighth week of the experiment revealed a 28 percent higher consumption for the antibiotic-fed pigs. These pigs consumed 13 percent more feed and gained 27.5 percent faster than the non-antibiotic-fed pigs during the same period.

The results of the carcass studies, as summarized in table 4, indicate no significant differences between antibiotic- and non-antibiotic-fed pigs. Viscera from all carcasses appeared normal. No observation could be made as to the effect of pantothenic acid on carcass quality.

Blood and urine studies were not made as deficiency symptoms did not appear.

Experiment II

The average daily gains, daily feed consumptions and feed efficiencies are shown in table 5. The analysis of variance of average daily gains is given in table 3.

While the basal-fed pigs made satisfactory gains (1.16 pound per day), the addition of 3.5 mg. of pantothenic acid to the ration increased the gains to 1.35 pound per day, which is significantly greater at P= 0.05. The addition of 10 mcg. vitamin B_{12} produced similar increases in gains significant at P=0.05. When both pantothenic acid and vitamin B_{12} were added, the daily gains obtained were no greater than those resulting from the addition of either vitamin B_{12} or pantothenic acid alone. No supplementary effects were apparent.

TABLE 5. SUMMARY OF GROWTH AND FEED DATA FOR EXPERIMENT II[1] (SUMMER—1951)[2]

Additions Per Pound of Basal Ration				
Pantothenic Acid	No Aureomycin		10 mg. Aureomycin	
	No Vit. B_{12}	10 mcg. B_{12}	No Vit. B_{12}	10 mcg. B_{12}
	Average Daily Gains (lb.)[3]			
0	1.16	1.32	1.57	1.56
3.5 mg.	1.35	1.28	1.56	1.58
	Average Daily Feed Consumed (lb.)			
0	3.84	4.07	4.75	4.75
3.5 mg.	4.36	4.04	4.53	4.77
	Feed Consumed Per 100 Pounds Gain (lb.)			
0	330	308	304	306
3.5 mg.	324	318	291	301

[1] Two lots of four pigs per treatment.
[2] On experiment 10 weeks.
[3] Average initial weight 32.5 lb.

Aureomycin-fed pigs made significantly (P=0.01) greater daily gains than those pigs fed vitamin B_{12}, pantothenic acid or a combination of the two in the absence of the antibiotic. The addition of pantothenic acid or vitamin B_{12} or both in the presence of aureomycin did not result in significant differences in daily gains. This is shown graphically in figure 2.

This suggests that vitamin B_{12} and pantothenic acid exert a "sparing" or "sparing-like" action on each other. Also, aureomycin appears to "spare" both vitamin B_{12} and pantothenic acid.

The feed efficiency was greatest with the use of aureomycin. This effect was significant (P=0.05). The addition of pantothenic acid or vitamin B_{12} in the presence of aureomycin did not affect feed efficiency.

The basal-fed pigs displayed considerable variation in size and condition at the end of the experiment. One animal scoured severely and lost some weight during one period. The pig's appetite improved follow-

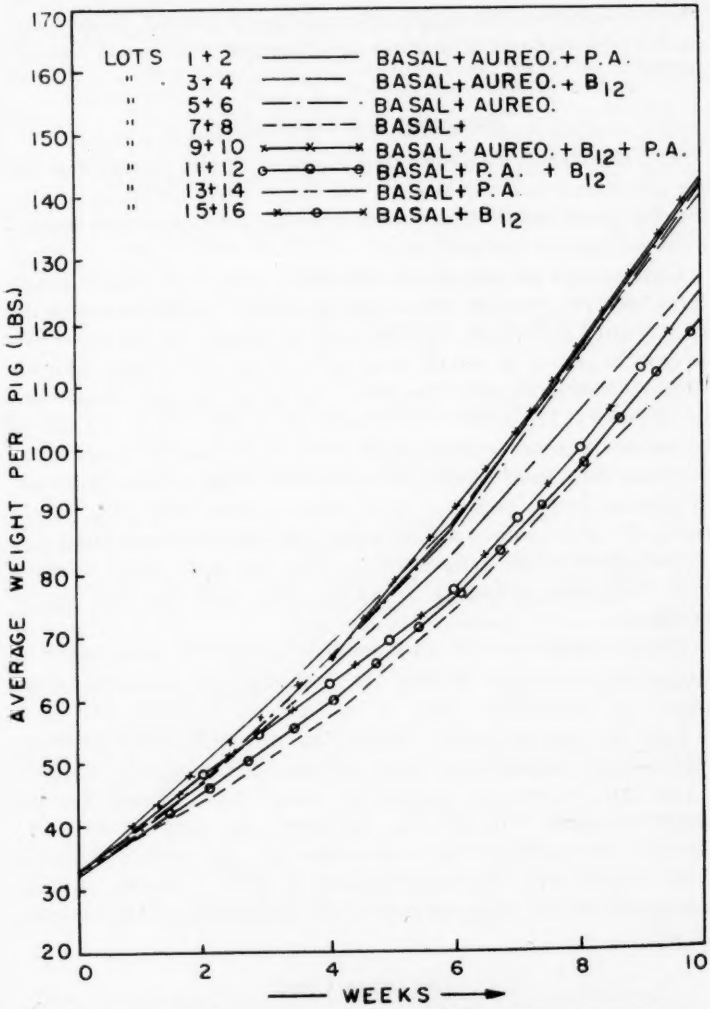


Figure 2. Growth curves of average weights per pig by ration treatments in experiment II.

ing a four day therapeutic treatment with aureomycin. Another pig on the basal ration developed a moderate weakness in the rear legs which resembled a vitamin B_{12} deficiency as observed by Richardson *et al.* (1951). This pig, though only mildly afflicted, appeared to recover when removed from test and placed on pasture. In contrast, the aureomycin-fed pigs were thrifty in appearance and quite uniform in size and condition.

Summary and Conclusions

Two experiments were conducted in concrete drylot to determine (1) the pantothenic acid requirements and (2) to study the effects of vitamin B_{12} and antibiotic supplementation on the pantothenic acid requirements of growing-fattening swine.

Corn-soybean oil meal rations assaying as low as 3.7 mg. of pantothenic acid per pound of ration were fed without producing any of the characteristic pantothenic acid deficiency symptoms. No significant differences in gains or in feed efficiency were produced with added amounts of pantothenic acid when the rations contained adequate vitamin B_{12} or antibiotics. The addition of 10 mcg. of vitamin B_{12} or 3.5 mg. of pantothenic acid per pound of basal ration, in the absence of antibiotics, increased daily gains significantly ($P=0.05$). The addition of 10 mg. of aureomycin per pound of ration also increased daily gains significantly ($P=0.01$) with or without either pantothenic acid or vitamin B_{12}.

Antibiotic-fed pigs consumed 28 percent more water and 13 percent more feed while gaining 27.5 percent faster than the pigs fed no antibiotics.

Carcass studies revealed no differences in back fat, body length or tissue moisture content between the antibiotic- and non-antibiotic-fed pigs.

From this work the authors conclude that vitamin B_{12} and pantothenic acid exert a "sparing" action on each other in the absence of aureomycin. Also, aureomycin appears to "spare" both vitamin B_{12} and pantothenic acid. With healthy, undepleted pigs weighing 35 to 45 pounds, a 14 percent protein corn-soybean oil meal ration balanced in other respects and containing adequate amounts of vitamin B_{12} and aureomycin need not be supplemented with pantothenic acid for optimum growth.

Literature Cited

Biely, J. and B. March. 1951. The effect of aureomycin and vitamins on the growth rate of chicks. Science 114:330.

Buskirk, H. H., A. M. Bergdahl and R. A. Delor. 1948. Enzymatic digestion of samples for microbiological assay of pantothenic acid. Jour. Biol. Chem. 172: 671.

Catron, D. V., H. M. Maddock, V. C. Speer, and R. L. Vohs. 1951. Effect of different levels of aureomycin with and without vitamin B_{12} on growing-fattening swine. Antibiotics & Chemotherapy 1:31.

Cravioto-Munzo, J., H. G. Poncher and H. A. Waisman. 1951. Vitamin B_{12} sparing action of aureomycin in the rat. Proc. Soc. Exp. Biol. and Med. 77:18.

Davis, R. L. and B. F. Chow. 1951. Content of radioactive vitamin B_{12} in the feces of rats fed Co^{60} and aureomycin. Proc. Soc. Exp. Biol. Med. 77:218.

Evans, R. J., A. J. Groschke and H. A. Butts. 1951. Effect of vitamin B_{12} on pantothenic acid metabolism in the chick. Arch. Biochem. & Biophysics 31:454.

Lepley, K. C., D. V. Catron and C. C. Culbertson. 1950. Dried whole aureomycin mash and meat and bone scraps for growing-fattening swine. JOURNAL OF ANIMAL SCIENCE 9:608.

Luecke, R. W., F. Thorp, Jr., W. N. McMillen and H. W. Dunne. 1949. Pantothenic acid deficiency in pigs fed diets of natural feedstuffs. JOURNAL OF ANIMAL SCIENCE 8:464.

Luecke, R. W., W. N. McMillen and F. Thorp, Jr. 1950. Further studies of pantothenic acid deficiency in weanling pigs. JOURNAL OF ANIMAL SCIENCE 9:78.

Luecke, R. W., F. Thorpe, Jr., H. W. Newland and W. N. McMillen. 1951. The growth promoting effects of antibiotics on pigs. JOURNAL OF ANIMAL SCIENCE 10:538.

McMillen, W. N., R. W. Luecke and F. Thorp, Jr. 1948. Pantothenic acid deficiency in swine on diets of natural feedstuffs. JOURNAL OF ANIMAL SCIENCE 7:529.

Richardson, D., D. V. Catron, L. A. Underkofler, H. M. Maddock and W. C. Friedland. 1951. Vitamin B_{12} requirement of male weanling pigs. Jour. of Nutr. 44:371.

Speer, V. C., H. M. Maddock, P. W. W. Cuff and D. V. Catron. 1951. Growth response of swine fed penicillin. Antibiotics & Chemotherapy 1:41.

Supplee, G. C., R. C. Bender and O. J. Kahlenberg. 1942. Interrelated vitamin requirements: kidney damage, adrenal hemorrhage and cardiac failure, correlated with inadequacy of pantothenic acid. Endocrinology 30:355.

Swick, R. W., H. Lih and C. A. Baumann. 1951. Contrasting effects of antibiotics in diets low in vitamin A or in members of the vitamin B complex. Fed. Proc. 10:395.

Vohs, R. L., H. M. Maddock, D. V. Catron and C. C. Culbertson. 1951. Vitamin B_{12}, APF concentrate, and dried whey for growing-fattening pigs. JOURNAL OF ANIMAL SCIENCE 10:42.

Yacowitz, H., L. C. Norris and G. F. Heuser. 1950. Evidence of interrelationships between vitamin B_{12} and riboflavin, pyridoxine and pantothenic acid. (abstract) Poultry Sci. 29:787.

DEVELOPMENT OF PRACTICAL SYNTHETIC MILK FORMULAS FOR BABY PIGS[1]

DAMON V. CATRON, LEROY F. NELSON, GORDON C. ASHTON and HELEN M. MADDOCK[2]

Iowa Agricultural Experiment Station[3]

CONSIDERABLE interest has developed in the raising of baby pigs on synthetic sows' milk. Several stations have published results on the successful rearing of baby pigs on a laboratory basis using synthetic milk but little work has been reported on the adaptation of synthetic milk for production purposes.

The three experiments reported herein were conducted to develop synthetic milk formulas and management practices applicable to the farm production of baby pigs.

Experiment I

Bustad and co-wokers (1948) reported that pigs removed from their dams at birth and placed on a synthetic milk containing the known vitamins and plasma or serum as a colostrum substitute failed to survive more than 22 days. However, Johnson *et al.* (1948) succeeded in raising pigs, which received colostrum for a minimum of 24 hours, on a synthetic milk which contained 30 percent vitamin-free casein, 37.4 percent cerelose, 26.6 percent lard, 6 percent salts plus 14 different fat- and water-soluble vitamins.

Experiment I was conducted to determine: (1) if pigs can be raised from birth to 56 days on a synthetic milk without receiving colostrum and (2) if the addition of lard or casein, or both to the milk are of benefit in increasing livability and growth.

Procedure

Four litters of Duroc pigs were taken from their dams immediately after farrowing and before obtaining colostrum. They were placed in wire-bottomed metal pens in a heated room and fed the synthetic milk

[1] This research was supported in part by a grant from Chas. Pfizer and Co., Inc., Brooklyn, New York.

[2] The authors gratefully acknowledge the assistance of Prof. Paul Homeyer in the statistical analysis of the data, and of Mr. Don Quinn and associates at the Swine Nutrition Research Farm.

[3] Journal Paper No. J-2086 of the Iowa Agricultural Experiment Station, Ames, Iowa. Animal Husbandry Department Project 959.

at refrigerator temperature in small pans. The composition of the simulated milk rations fed the different lots of pigs are shown in table 1.

The pigs were given the amount of milk they would consume 6 times per day until the 18th day. The number of milk feedings per day was gradually decreased to three by the 38th day. The solids content of the milk was increased from 18 percent to 24.4 percent at the end of the third week. The amount of milk fed was gradually reduced during the

TABLE 1. COMPOSITION OF MILK RATIONS USED IN EXPERIMENT I

Ration Number	I	II	III	IV
Ration Treatment	Basal	Basal Incl. Lard	Basal Incl. Casein	Basal Incl. Lard and Casein
Dried skimmed milk, lb.	100	70.3	83.0	53.3
Lard, lb.	...	29.7	....	29.7
Casein, lb.	...	....	17.0	17.0
Vitamins, antibiotics and minerals added per pound of solids in total ration:				
Alpha-tocopherol acetate, mg.	7.37	Naphthaquinone, mcg.		656.00
Ascorbic acid, mg.	40.40	Aureomycin HCl, mg.		20.00
Biotin, mcg.	25.20	Terramycin HCl, mg.		20.00
Calcium pantothenate, mg.	19.69	Procaine penicillin G, mg.		20.00
Choline chloride, mg.	328.00	Streptomycin SO_4, mg.		20.00
Folic acid, mg.	0.13	NaCl, gm.		2.41
Niacin, mg.	6.56	$MgSO_4$, mg.		719.00
Para-amino-benzoic acid, mg.	6.56	Ferric Citrate·$6H_2O$, mg.		393.00
Pyridoxine HCl, mg.	3.28	KI, mg.		11.30
Riboflavin, mg.	3.28	$MnSO_4$, mg.		20.20
Thiamin HCl, mg.	1.64	$ZnCl_2$, mg.		3.28
Vitamin B_{12}, mcg.	20.00	$CuSO_4 \cdot 5H_2O$, mg.		4.04
Vitamin A, I.U.	12,000	$CoCl_2$ mg.		1.36
Vitamin D_2, I.U.	6,313	CaF_2, mg.		6.56

two weeks preceding the termination of the experiment at 56 days. No record of milk consumption was kept, but all of the pigs received the same amount of milk per feeding.

On the 18th day a palatable pig starter, similar to the one in table 3, and shelled corn were self-fed. At 34 days of age the pigs were moved to concrete-floored pens.

Results and Discussion

A summary of the data for this experiment is presented in table 2. With the exception of one pig, we were not successful in raising baby

pigs that had not received colostrum, without a dietary source of fat. The sole surviving pig in lot I, at 5 days of age, was very emaciated and was not expected to live; therefore it was transferred to lot IV. There was no evidence of disease in the pigs during this experiment.

The growth rates of pigs on the lard-dried skimmed milk diet (lot II) and those on the lard-casein-dried skimmed milk diet (lot IV) were practically the same. The lot II pigs were slightly superior to the lot IV pigs in rate of gain up to the sixth week. When milk consumption was decreased after the sixth week, there was a marked increase in

TABLE 2. SUMMARY OF RESULTS OF EXPERIMENT I

Ration Number	I	II	III	IV
Ration Treatment	Basal	Basal Incl. Lard	Basal Incl. Casein	Basal Incl. Lard and Casein
No. pigs started	7	12	6	12
Av. initial wt. (lb.)	2.44	2.47	2.80	2.50
No. pigs dead: 1 to 3 days	3	5	2	4
4 to 17 days	3	1	4	1
No. pigs at 56 days	0[1]	6	0	8[1]
Av. wt./pig 56 days		43.4		45.6
Av. pig starter/pig (lb.)		17.9		22.3
Av. shelled corn/pig (lb.)		1.5		5.9
Total feed/pig[2]		19.4		28.2

[1] One pig was transferred at 5 days of age from Lot I to IV after all other pigs had died in Lot I.
[2] Does not include milk solids as no record was kept.

the gains of the pigs in both lots. However, the pigs in lot IV gained somewhat faster and averaged 2.2 pounds heavier than the pigs in lot II at the end of the experiment. The heavier final weight of the lot IV pigs is not believed to be due to the casein in the diet, but rather to the greater amount of pig starter and shelled corn consumed. Perhaps casein had an indirect effect inasmuch as the pigs fed the casein-lard-skimmed milk diet consumed more solid feed than the pigs on the lard-skimmed milk diet. The reasons for this is not evident. Two additional pigs, including the one transferred from the non-fat diet (lot I), were raised on the casein-lard-skimmed milk diet.

The results of this experiment would indicate that baby pigs can be raised satisfactorily without colostrum if the synthetic diet is adequate and if there is a low disease level in the environment. Young and Underdahl (1951) were able to raise pigs on a modified cows' milk

diet without colostrum when they caught the pigs at birth in a sterilized bag and transferred them to an isolated laboratory environment.

Experiment II

In the first experiment it was observed that there was a marked increase in growth rate during the transitional feeding period from the synthetic milk to the dry pig starter. With this in mind, the second experiment was conducted to determine at what age pig starter could replace the synthetic milk without affecting pig performance adversely.

TABLE 3. COMPOSITION OF PIG STARTER RATION EXPERIMENT II[1]
(Per 100 Pounds)

Ingredients	lb.	Ingredients	gm.
Oat groats (rolled)	25.0	Terramycin	1.3
Rolled oats (steamed)	25.0	9-F irradiated yeast[4]	6.8
Gr. yellow corn	20.0	Tru-A-Oil[5]	22.0
50% Meat and bone scraps	2.5	Riboflavin	0.25
44% Solv. soybean oil meal (blended)	16.0	Niacin	2.5
Dried whey	2.5	Calcium pantothenate	0.5
Molasses (cane)	5.0	Choline chloride	20.0
Bi-Con 3+1[2]	0.7		
Calcium carbonate (iodized)	1.0		
Sp. steamed bonemeal	1.5		
Salt (iodized)	0.5		
Trace mineral premix[3]	0.2		

[1] Fed in crumblized form Exp. II and crumblized and pelletted form Exp. III.
[2] Contained 3 mg. vitamin B_{12} and 1 gm. terramycin per pound.
[3] Contained the following: 7.0% Fe, 0.48% Cu, 0.16% Co, 0.45% Zn, 5.9% Mn and 14.2% Ca.
[4] Contained 4 million I.U. vitamin D_2 per pound.
[5] Contained 9,000 I.U. vitamin A per gram.

Procedure

Six lots of 10 pigs each were fed the same synthetic milk. The synthetic milk formula was similar to ration II in experiment I except that it contained 23.6 percent fat, 3.26 percent lecithin, and 10.2 percent fish solubles. It was reconstituted with water to provide a 20-percent-solids milk. Two lots of pigs were fed the synthetic milk for 7 weeks, two for 6 weeks, and two for 5 weeks.

It was originally planned that the pigs would not receive colostrum, but after the first litters died with transmissible gastroenteritis all pigs were permitted to nurse their dams for 48 hours. The pigs were raised in concrete-floored pens with radiant floor heat. Milk was full-fed by hand 5 times a day until the pigs were three weeks old, then feeding

was reduced to 4 times a day. The milk that was not consumed after each feeding was weighed back. The quantity of milk fed was gradually decreased during the last week of milk feeding. Pig starter (table 3) was provided in a self-feeder when the pigs were one week old.

Results and Discussion

The summary of the pig weights and feed consumption is presented in table 4.

TABLE 4. AVERAGE PIG WEIGHTS AND CUMULATIVE FEED CONSUMPTION PER PIG BY WEEKS IN EXPERIMENT II

	Age in Weeks								
	Birth	1	2	3	4	5	6	7	8
	(Pounds)								
Lots 1 & 2—Milk-fed 7 weeks (20 pigs)									
Av. wt./pig	2.6	3.0	4.2	5.8	8.3	12.0	17.4	23.0	30.6
Milk solids		0.5[1]	1.7	3.6	5.8	8.7	12.6	16.3	
Pig starter			0.4	0.5	0.9	2.4	5.7	11.8	27.2
Feed solids/lb. gain									1.55
Lots 3 & 4—Milk-fed 6 weeks (19 pigs)									
Av. wt./pig	3.1	3.7	4.7	6.9	9.5	14.1	19.0	25.2	34.2
Milk solids		0.5[1]	1.6	3.5	5.7	8.5	12.0		
Pig starter			0.2	0.6	1.4	3.8	7.3	19.6	38.5
Feed solids/lb. gain									1.63
Lots 5 & 6—Milk-fed 5 weeks (19 pigs)									
Av. wt./pig	2.8	3.0	4.1	5.9	8.6	12.5	16.2	23.4	31.5
Milk solids		0.5[1]	1.6	3.4	5.5	8.0			
Pig starter			0.2	0.6	1.6	4.0	12.1	24.6	41.3
Feed solids/lb. gain									1.80

[1] Includes only 4 days of synthetic-milk feeding during the first week.

Shortening the milk feeding period from 7 to 5 weeks did not reduce the final 56-day pig weights; however, it resulted in lower milk solids consumption (decreased from 16.3 to 8.0 pounds) and a higher intake of pig starter (increased from 27.2 to 41.3 pounds).

An outbreak of transmissible gastroenteritis which occurred in the baby pigs at the beginning of this experiment appeared to affect all lots of pigs to the same degree. We failed to raise pigs without colostrum in the presence of transmissible gastroenteritis. Although only two pigs which had received colostrum died, the disease impaired their health and growth rate during the first part of the experimental period. Most of the pigs exhibited noticeable diarrhea and general unthriftiness.

TABLE 5. RATION TREATMENTS FOR EVALUATION OF FAT AND SOLIDS LEVELS (NO REPLICATION) EXPERIMENT III

	Fat Levels[1]		
	10%	20%	30%
Solids Levels	Formula[2]	Formula	Formula
15%	A_1	B_1	C_1
20%	A_2	B_2	C_2
25%	A_3	B_3	C_3

[1] Includes lard plus lecithin.
[2] The formulas will be found in table 7.

Even in the presence of this disease condition, the average weight per pig at 56 days of age was 32.1 pounds.

Experiment III

In studies with antibiotics, Wahlstrom and co-workers (1950) showed that aureomycin, but not penicillin or sulfathalidine, stimulated growth of baby pigs on an alpha-protein synthetic milk. Results from Sheffy *et al.* (1952) indicate that aureomycin gave a greater growth response than did streptomycin. Nesheim and associates (1950) and Nesheim and Johnson (1950) obtained significant increases in growth rate and feed efficiency with streptomycin in two experiments, but in another experiment (Nesheim *et al.* 1950) no significant increases in rate of gain were observed with the addition of aureomycin, penicillin, or streptomycin.

Experiment III was conducted to study the effects of various levels of fat and solids, extra vitamin fortification, terramycin versus a combination of antibiotics, and condensed fish solubles in synthetic milk formulas.

TABLE 6. RATION TREATMENTS FOR EVALUATION OF EXTRA VITAMIN FORTIFICATION, FISH SOLUBLES, AND TERRAMYCIN VS. A COMBINATION OF ANTIBIOTICS (TWO REPLICATES) EXPERMENT III

	1X Level Vitamins	2X Level Vitamins
Ration treatment	Formula	Formula
Terramycin+Fish Solubles	B_2[1]	B_4
Combination Antibiotics+Fish Solubles	D_1	D_2
Combination Antibiotics+No Fish Solubles	E_1	E_2

[1] The lot of pigs on formula B_2 in table 5 was used as the first replicate in table 6.

Plans and Rations

The ration treatments were fitted into two factorial experimental plans: (1) a 3 x 3 factorial comparing three levels of solids and three levels of fat, and (2) a 2 x 3 factorial comparing two levels of vitamin fortification, a single versus a combination of antibiotics, and the absence

TABLE 7. COMPOSITION OF SYNTHETIC MILK RATIONS USED IN EXPERIMENT III

Formulas[1]	$A_1A_2A_3$	$B_1B_2B_3B_4$	$C_1C_2C_3$	D_1D_2	E_1E_2
Fat, %	10	20	30	20	20
Fish Solubles, %	10	10	10	10	0
Antibiotic (50 mg./lb. solids)	Terramycin	Terramycin	Terramycin	Combination[2]	Combination
Dried skimmed milk, lb.	82.25	71.65	61.05	71.65	82.25
Condensed fish solubles, lb.	10.00	10.00	10.00	10.00	.....
Lecithin, lb.	3.70	3.70	3.70	3.70	3.70
Lard, lb.	6.30	16.30	26.30	16.30	10.87
Corn oil, lb.	.....	.....	.....	.....	5.43
NaCl, lb.	0.75	0.75	0.75	0.75	0.75
$CaCO_3$, lb.	0.80	0.80	0.80	0.80	0.80
$CaHPO_4$, lb.	0.20	0.80	1.40	0.80	0.20
Vitamin premix, gm.[3]	263	263	263	263	263
Trace mineral premix, gm.[4]	162	162	162	162	162

[1] Formulas A_1 B_1 and C_1 mixed with water to make 15% solids.
Formulas A_2, B_2, 4 C_2 D_1, 2 and E_1, 2 mixed to make 20% solids.
Formulas A_3 B_3 and C_3 mixed with water to make 25% solids.

[2] Combination of 12.5 mg. each of terramycin, rimocidin, streptomycin and penicillin.

[3] Contributed the following vitamins per lb. of total solids:

1X Vitamin Level—Formulas A_1, 2, 3 B_1, 2, 3 C_1, 2, 3 D_1 and E_1

Thiamin HCl, mg.	2.27	Biotin, mg.	0.03
Riboflavin, mg.	4.54	Folic acid, mg.	0.18
Pyridoxine HCl, mg.	4.54	Ascorbic acid, mg.	5.59
Calcium pantothenate, mg.	27.27	Vitamin B_{12}, mcg.	30.0
Inositol, mg.	90.90	Vitamin A, I.U.	12,000
Niacin, mg.	9.09	Vitamin D_2, I. U.	2,000
Para-amino-benzoic acid, mg.	9.09	Alpha-tocopherol acetate, mg.	3.49
Choline chloride, mg.	454.54	Napthaquinone, mg.	0.91

2X Vitamin Level—Formulas B_4 D_2 and E_2 (twice above amounts)

[4] Contributed the following trace minerals per lb. of total solids: $MgSO_4$, 719.00 mg; Ferric citrate, 555.00 mg; KI 16.29 mg; $MnSO_4.H_2O$, 31.60 mg; $ZnCl_2$, 4.79 mg; $CuSO_4.5H_2O$, 5.75 mg; $CoCl_2.6H_2O$, 3.50 mg; CaF_2, 9.58 mg.

versus the addition of condensed fish solubles. The experimental plans of the ration treatments are shown in tables 5 and 6. Although replicate pens on all fifteen rations would have been desirable, limitations of space permitted replication of only six of the rations. The 3 x 3 factorial consisted of single pens per treatment. One of the ration treatments (B_2) from the 3 x 3 factorial was used to complete the replication of the 2 x 3 factorial.

The composition of the synthetic milk rations are given in table 7. The composition of the pig starter fed in this experiment was modified from that fed in the second experiment by (1) substituting 60 percent red fish meal for 50 percent meat and bone scraps, and (2) substituting cane sugar for molasses (table 3).

Figure 1. Two pens of pigs in Experiment III showing the arrangement and type of equipment used.

Procedure

Twenty lots of 5 Poland China x Landrace x Duroc pigs were taken from their dams and started on experiment at an average age of three days. The pigs were left with their dams in farrowing crates for this period in order to receive colostrum. The rations were assigned to the lots at random and the pigs were allotted to the ration treatments as they farrowed. In every case, at least two litters were represented in each lot. The pigs were confined in radiant-heated, concrete-floored pens with heat lamps suspended from above (see figure 1). At the beginning of the experiment, the floor temperature under the heat lamps was between 90 and 95° F. Floor temperatures were gradually reduced after the first week by raising the heat lamps. The lamps were removed at the end of the fourth week. The initial room temperature of

73° F. was gradually reduced to 58° F. by the end of the experiment.

Synthetic milk was added twice daily to three-gallon automatic poultry water fountains. The unconsumed milk was weighed back once daily before the next addition. The milk was fed warm for the first two days and at room temperature thereafter. The milk was full-fed for the first three weeks then it was gradually decreased until terminated at the end of the fifth week.

The extra vitamin fortification was added at feeding time. This was done to check the stability of the vitamins in the dry synthetic formula as well as in the reconstituted milk. The milk solids were reconstituted each afternoon for that evening's and the next morning's feeding. Water was provided *ad libitum* the second day the pigs were on experiment. In order to evaluate the different experimental synthetic milks, the pig starter was not provided in self-feeders until the pigs had been on experiment 16 days. All lots of pigs were terminated after 8 weeks on experiment.

Results and Discussion

Of the 100 pigs started, 97 were raised successfully to 59 days of age. The average weekly cumulative pig weights and feed consumption by treatments are presented in table 8 and certain analyses of variance are given in table 9. The mean square between pens fed the same rations was used as the estimate of experimental error for all treatment

TABLE 8. AVERAGE PIG WEIGHTS AND AVERAGE CUMULATIVE FEED CONSUMPTION PER PIG BY WEEKS IN EXPERIMENT III

Treatment	Weeks on Experiment								
	Initial[1]	1	2	3	4	5	6	7	8
	(Pounds)								
15 % Solids (15 pigs)									
Av. wt./pig	3.8	5.4	8.2	13.3	19.0	27.1	34.8	45.7	54.0
Milk solids		1.7	3.6	8.9	14.6	18.9			
Pig starter				0.7	3.4	9.6	25.1	44.8	69.5
Feed solids/lb. gain.									1.76
20% Solids (15 pigs)									
Av. wt./pig	3.9	5.2	7.8	12.6	17.2	23.8	29.6	40.2	50.1
Milk solids		1.9	5.0	10.6	16.8	23.4			
Pig starter				0.5	2.0	5.6	18.5	36.8	61.0
Feed solids/lb. gain									1.81
25% Solids (14 pigs)									
Av. wt./pig	3.9	4.8	8.0	11.7	17.5	24.5	31.3	38.2	47.2
Milk solids		2.0	6.3	11.7	18.3	24.1			
Pig starter				0.7	1.8	6.0	18.2	36.5	58.8
Feed solids/lb. gain									1.88

TABLE 8.—*Continued*

Treatment	Initial[1]	Weeks on Experiment 1	2	3	4	5	6	7	8
					(Pounds)				
10% Fat (15 pigs)									
Av.wt./pig	3.9	5.3	8.5	14.1	19.7	26.8	34.1	44.4	54.2
Milk solids		1.7	4.9	10.5	17.4	23.0			
Pig starter				0.6	2.3	8.1	23.6	43.8	69.6
Feed solids/lb. gain.									1.84
20% Fat (14 pigs)									
Av. wt./pig	3.8	5.2	8.3	12.7	18.8	26.0	34.6	42.7	52.4
Milk solids		1.9	5.6	10.8	16.8	21.9			
Pig starter				0.6	2.5	7.3	22.0	41.6	65.7
Feed solids/lb. gain.									1.80
30% Fat (15 pigs)									
Av. wt./pig	4.0	5.0	7.3	10.8	15.3	22.7	29.1	39.9	48.1
Milk solids		2.1	5.0	9.9	15.4	20.4			
Pig starter				0.7	2.4	5.8	16.5	33.1	54.6
Feed solids/lb. gain									1.83
1X Level Vitamins (28 pigs)									
Av. wt./pig	3.6	4.9	7.6	12.4	18.5	24.8	31.3	39.5	49.4
Milk solids		1.7	4.9	9.9	16.3	22.4			
Pig starter				0.5	1.5	4.9	17.1	36.1	57.9
Feed solids/lb. gain									1.74
2X Level Vitamins (30 pigs)									
Av. wt./pig	3.7	5.0	7.2	11.7	18.2	25.1	31.6	39.8	49.8
Milk solids		1.8	4.9	9.2	15.4	21.4			
Pig starter				0.5	1.8	6.3	18.9	37.2	59.0
Feed solids/lb. gain									1.73
Terramycin+Fish Solubles (20 pigs)									
Av. wt./pig	3.5	4.8	6.7	11.5	17.6	23.6	30.2	38.8	49.7
Milk solids		1.7	4.8	9.3	15.7	21.7			
Pig starter				0.5	1.5	4.9	17.2	35.9	57.9
Feed solids/lb. gain									1.72
Combination Antibiotics+Fish Solubles (20 pigs)									
Av. wt./pig	3.8	5.0	7.5	11.8	18.0	24.8	31.1	39.0	47.9
Milk solids		1.8	5.0	9.7	15.7	21.7			
Pig starter				0.6	1.9	5.7	18.2	36.6	57.8
Feed solids/lb. gain									1.80
Combination Antibiotics—No Fish Solubles (18 pigs)									
Av. wt./pig	3.6	5.1	8.0	12.8	19.5	26.6	33.1	41.3	51.4
Milk solids		1.7	4.9	9.6	16.1	22.2			
Pig starter				0.5	1.6	6.3	18.6	37.7	59.9
Feed solids/lb.gain									1.70
Average All Treatments (97 pigs)									
Av. wt./pig	3.7	5.0	7.6	12.2	18.1	25.0	31.5	40.4	49.8
Milk solids		1.7	5.0	9.9	16.1	22.0			
Pig starter				0.6	2.0	6.3	19.0	37.5	60.0
Feed solids/lb. gain									1.78

[1] Pigs averaged 3 days of age.

TABLE 9. ANALYSES OF VARIANCES FOR EXPERIMENT III

Source of Variation	d.f.	Liveweight				Total Solids Consumed		Feed per lb. Gain			
		2 weeks		8 weeks		2 weeks		2 weeks		8 weeks	
		MS	F	MS	F	MS	F	MS	F	MS	F
Levels of fat	2	1.124		65.06	9.5*	0.246		1324.9	1.2	13.8	
Linear component	1	2.053	1.6	120.60	17.6**	0.066		2637.6	2.5	0.7	
Quadratic component	1	0.194		9.53	1.4	0.426		12.2		26.9	
Levels of solids	2	0.323		80.40	11.7*	2.679	4.8	2442.3	2.3	168.4	2.3
Linear component	1	0.126		79.94	11.6*	5.358	9.7*	4799.7	4.5	322.7	4.5
Quadratic component	1	0.203		0.47		0.000		84.9		14.5	
Fat levels x solids levels	4	0.296		3.24		0.160		318.4		11.9	
Levels of vitamins	1	0.411		0.10		0.023		1356.8	1.3	2.1	
Antibiotic & fish solubles	2	1.523		11.50	1.7	0.051		1927.0	1.8	115.5	1.6
Combination vs. terramycin	1	1.264		7.80	1.1	0.080		812.0		105.1	1.5
Nil vs. fish solubles	1	0.353		22.78	3.3	0.000		1123.4	1.1	220.5	3.1
Vitamins x antibiotics	2	0.224		11.91	1.7	0.077		76.4		40.1	
Between pens fed same rations[1]	6	1.286		6.87		0.552		1060.6		71.9	

* Significant at P=0.05.
** Significant at P=0.01.
[1] Estimate of experimental error.

comparisons made. This is the correct estimate for comparing gains made on the rations forming the 2 x 3 factorial. It was consideerd a valid estimate of error for comparing the effects of the rations forming the 3 x 3 factorial since all 20 pens were in the same building during the same period of time and since there was a common source of pigs.

As the pig starter was offered to all pigs at the end of two weeks on experiment, the milk rations constituted the only ration for these two weeks. Analysis of the first two-week data showed no significant treatment differences in live weights, however, the consumption of milk solids increased significantly (P=0.05) with increasing solids in the rations. There was an apparent tendency for the efficiency of the rations to decrease as both the fat and solids levels were increased.

For the overall experimental period, the best synthetic milk formula A_1 (10 percent fat and 15 percent solids) and the poorest formula C_3 (30 percent fat and 25 percent solids) produced pigs that averaged 57.7 and 43.4 pounds, respectively. The 97 pigs averaged 49.8 pounds at the termination of the experiment. In figure 2 are the growth curves for these three groups of pigs compared to a reference growth curve reported by Forshaw *et al.* (1950) based on 1296 Duroc pigs which nursed their dams for 8 weeks.

Although all pigs received the same pig starter, there were significant (P=0.05) increases in the final weights of the pigs. The milk solids consumed per pig decreased and the pig starter consumed per pig increased as the solids level in the reconstituted synthetic-milk formula was decreased.

Decreasing the fat content of the milk increased significantly (P= 0.05) the final pig weights but did not affect feed efficiency. The consumption of both the milk solids and pig starter tended to increase as the fat level in the synthetic milk was decreased.

No significant differences in pig performance were found by including extra vitamin fortifications, a combination of antibiotics, or condensed fish solubles in the synthetic milk. The final average pig weight, feed efficiency, and total feed consumed per pig were almost identical whether extra vitamins were added at the time of feeding or not. This indicates that there was no appreciable loss in the stability of the vitamins in the milk solids or in the liquid milk. The replacement of terramycin by a combination of four antibiotics also failed to improve performance. Although there was a 4 pound advantage in the average final weights of the pigs receiving no condensed fish solubles this differences was not statistically significant.

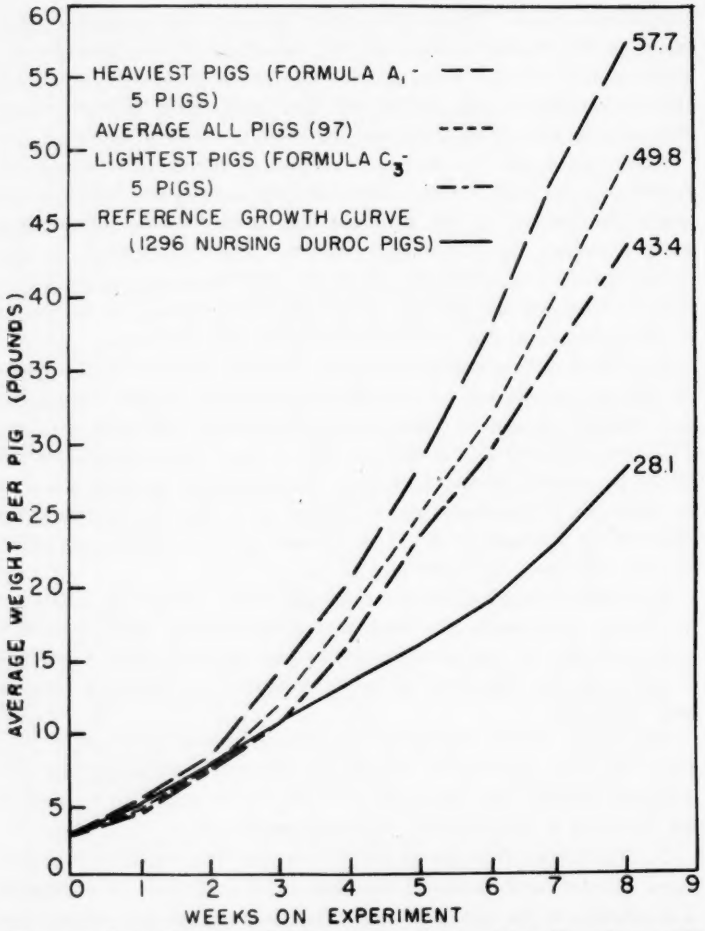


Figure 2. Growth curves of three groups of pigs from Experiment III compared to a reference growth curve.

All pig mortalities were submitted to the Veterinary Diagnostic Laboratory for examination. One pig died during the second week from an acute catarrhal enteritis, another at the end of 5 weeks because of post-castration peritonitis, and the third died during the sixth week from hemorrhagic pericarditis and pleuroperitonitis. The 97 pigs finishing the experiment exhibited excellent health as indicated by skin and

hair coats. Post-weaning performance of the pigs managed outside in winter drylot with portable equipment was satisfactory.

Summary

Three experiments were conducted to develop a practical synthetic sow-milk substitute and to study its performance under experimental farm conditions.

In the apparent absence of disease, it was possible to raise 14 pigs, which had not received colostrum, on a vitamin, mineral and antibiotic fortified dried skimmed milk ration including lard. The addition of casein did not improve growth but without lard the pigs died.

After an outbreak of transmissible gastroenteritis in the second experiment, it was impossible to raise pigs without colostrum. Six lots of 10 pigs raised from 2 days of age in concrete-floored pens indicated that 56-day weights were not reduced by discontinuing milk feeding at 5 weeks as compared with 7 weeks of age.

In a third experiment, twenty lots of 5 pigs each were raised successfully from 3 days of age in radiant-heated, concrete-floored pens. Of the 10, 20 and 30 percent fat levels, the lowest level produced the best growth. A level of 15 percent solids was superior to 20 or 25 percent for growth, feed efficiency and physical reconstitution. When fed at equal levels, a combination of terramycin, streptomycin, penicillin and rimocidin gave no better results than terramycin alone. The inclusion of 10 percent condensed fish solubles failed to improve performance. Doubling the vitamin fortification did not improve gains or feed efficiency. This would indicate that sufficient vitamin fortification was provided in the basal synthetic milk and that the vitamins were sufficiently stable in the milk solids and in the reconstituted milk. The 97 pigs raised averaged 49.8 pounds at approximately 8 weeks of age and consumed an average of 22 pounds of milk solids and 60 pounds of pig starter to this age. Post-weaning performance of the pigs fed synthetic milk was satisfactory.

The results of these experiments indicate baby pigs can be raised successfully from 2 to 3 days of age in concrete-floored pens on synthetic milk rations composed of dried skimmed milk, lard, essential minerals, vitamins and antibiotics.

Literature Cited

Bustad, L. K., W. E. Ham and T. J. Cunha. 1948. Preliminary observations on using a synthetic milk for raising pigs from birth. Arch. Biochem. 17:247.

Forshaw, R. P., H. M. Maddock, P. G. Homeyer and D. V. Catron. 1950. A proposed growth curve for nursing Duroc pigs raised in drylot. JOURNAL OF ANIMAL SCIENCE 9:655.

Johnson, B. C., M. F. James and J. L. Krider. 1948. Raising newborn pigs to weaning age on a synthetic diet with attempt to produce a pteroylglutamic acid deficiency. JOURNAL OF ANIMAL SCIENCE 7:486.

Nesheim, R. O., J. L. Krider and B. C. Johnson. 1950. Antibiotics, whey and APF for baby pigs. JOURNAL OF ANIMAL SCIENCE 9:664.

Nesheim, R. O. and B. C. Johnson. 1950. Response of pigs to streptomycin. Proc. Soc. Exp. Biol. Med. 75:709.

Sheffy, B. E., R. H. Grummer, P. H. Phillips and G. Bohstedt. 1952. Comparison of growth responses of 2-day-old pigs to streptomycin, aureomycin, and crude APF, alone and in combination with B_{12}. JOURNAL OF ANIMAL SCIENCE 11:97.

Wahlstrom, R. C., S. W. Terrill and B. C. Johnson. 1950. Effect of anti-bacterial agents on growth of baby pigs fed a "synthetic diet". Proc. Soc. Exp. Biol. Med. 75:710.

Young, G. A. and N. R. Underdahl. 1951. A diet and technic for starting pigs without colostrum. Arch. Biochem. and Biophys. 32:449.

DEHYDRATED ALFALFA AND ANTIBIOTIC SUPPLEMENTS IN GESTATION-LACTATION RATIONS FOR SWINE[1]

J. G. De Pape,[2] Wm. H. Burkitt,[3] and A. E. Flower

Montana Agricultural Experiment Station

THE value of alfalfa meal as a practical source of the water soluble vitamins was demonstrated by Krider, *et al.* (1945) by increasing the pigs weaned from 13 percent to levels as high as 48 percent, 50 percent, and 83 percent with various supplementations. The basal ration was composed of soybean oil meal, tankage, fish meal, minerals, salt, and cod-liver oil but no alfalfa. The addition of 4 percent alfalfa meal and 6 percent distillers corn solubles or 10 percent alfalfa meal improved breeding efficiency and fertility as well as the strength of the pigs farrowed. The value of the alfalfa meal and the solubles was attributed to the water-soluble vitamins, known or unknown, contained in these products.

The nutritional inadequacy of a basal diet composed essentially of corn, soybean oil meal, and 5 percent dehydrated alfalfa for gestation and lactation was demonstrated by Krider, *et al.* (1946). The addition of 3 percent or 6 percent condensed fish solubles raised the percentage survival of pigs weaned from 26 to 92 percent. In another trial Krider, *et al.* (1948), using the same basal as the above, indicated that the addition of 0.5 percent, 1.0 percent or 2.0 percent of B-Y, a riboflavin supplement, did not correct the deficiency of the basal ration. The addition of 10 percent high quality dehydrated alfalfa meal, as a source of water-soluble vitamins, to a plant protein basal ration did not improve significantly the gestation-lactation performance in three swine experiments reported by Catron, *et al.* (1948). Furthermore, addition of animal protein to the basal ration fed to the sows during gestation and/or lactation failed to increase pig livability and growth. Heidebrecht, *et al.* (1950) reported that gilts and sows fed basal rations (essentially corn, soybean oil meal and 5 percent alfalfa) performed as well during reproduction and lactation as did gilts and sows fed the

[1] Contribution from the Department of Animal Industry and Range Management, Montana State College, Agricultural Experiment Station. Paper No. 271, Journal Series.

[2] The data in this paper are taken in part from a thesis submitted to the Graduate School of Montana State College in partial fulfillment for the degree of Master of Science in Animal Industry.

[3] Present address: Colorado Milling and Elevator Company, Ranch-Way Division, Denver 2, Colorado.

basal ration fortified with either 10 percent alfalfa, iodine, vitamin A, or APF supplement no. 1 and 2 (Merck), or those injected with liver extract (Lederle). In a second trial using APF no. 5 (Merck), the supplemented group raised more pigs than the sows fed the basal and the pigs weighed slightly more at weaning.

Anderson (1949), using a very limited number of gilts, showed that the animals on a basal of corn, soybean oil meal, tankage, alfalfa meal, cod-liver oil, trace mineralized salt, and bonemeal, farrowed more and larger pigs than those receiving, in addition to the basal, a B_{12} concentrate or fish meal. However, the gilts in the vitamin B_{12} and fish meal groups lost fewer pigs and their litters were heavier at weaning. Ensminger, *et al.* (1951) indicated that a purified basal diet was nutritionally inadequate for satisfactory reproduction and lactation for the sow. Some factor or factors, either one or more of the other known B-complex vitamins not included in the purified ration used, or some unknown factors (s) are essential for reproduction and lactation in swine.

From the experimental evidence to date, Catron (1952) indicates that antibiotic feeding has no effect on (1) size of the litter, or (2) the strength or weight of the pigs at birth. Antibiotics can be detected in milk from sows on rations containing as little as 10 mgs. of antibiotics per pound of ration, and this feeding reduces the incidence of scouring in nursing pigs. The inclusion of antibiotics in a well-balanced ration did not have any affect on the conception percentage. Carpenter (1951) obtained an increase in weaning weight of pigs from 25 to 36 pounds by feeding sows a diet supplemented with 0.5 percent APF concentrate containing aureomycin and providing a creep feeding diet that contained 1 percent of the supplement. The author indicated that the weanling growth stimulation was due to aureomycin in the APF supplement of the creep diet and not due to any substance transferred to the pigs through the milk. Feeding of the supplement 49 to 90 days prior to parturition was reported to have no effect on litter size and livability or on birthweight of pigs.

The experiments reported herein were conducted to study the effect of (1) supplementing a ration containing animal protein of natural origin with an aureomycin-APF concentrate, and (2) substituting dehydrated alfalfa pellets for sun-cured alfalfa meal in gestation-lactation rations for sows and gilts, on the birth weight, weaning weight and livability of the offspring.

Experimental Procedure

Purebred Duroc and Montana No. 1[4] sows and gilts were allocated and equalized as nearly as possible according to breed and production potential as judged by the number of pigs farrowed per female in previous litters for sows, and by number of litter mates weaned for gilts. Equal numbers of gilts were put in each group and they were distributed on the basis of their dams' reproductive performance. Sows and gilts were assigned to boars equalizing the number of females in

TABLE 1. PRE-BREEDING AND GESTATION RATIONS FOR SOWS AND GILTS

Lot number	1 %	2 %	3 %
Barley	60.0	60.0	60.0
Wheat	13.0	13.5	13.0
Soybean oil meal	7.0	7.0	7.0
Meat and bone meal (52% protein)	4.0	4.0	4.0
Sun-cured alfalfa meal (17.6% protein)	15.0	15.0	....
Dehydrated alfalfa pellets (20.6% protein)	....	....	15.0
Salt	0.5	0.5	0.5
Calcite	0.5	0.5	0.5
APF Supplement[1]	....	0.5	....
Crude protein (percent)	15.1	15.0	15.3
Calcium (percent)	0.6	0.6	0.6
Phosphorous (percent)	0.5	0.5	0.5

[1] Lederle's APF Supplement No. 5 and "Fortafeed" supplied by courtesy of Dr. T. H. Jukes, Lederle Laboratories, Pearl River, New York.
All rations fortified with 750 I.U. vitamin D per pound of feed.
All rations fortified with 1 pound per ton of Lederle "Fortafeed" B-complex supplement.
All rations fortified with 10 ppm Cu, 50 ppm Fe, 25 ppm Mn, and 1 ppm Co.

each group serviced by each boar. No brother-sister matings were made, however, some of the gilts were crossbred.

The females were kept in adjacent pasture lots with houses provided for shelter during the winter months. The animals had access at all times to fresh creek water. Approximately a week prior to the calculated farrowing date, the animals were moved into their farrowing quarters.

The animals were fed, once daily, a measured amount of feed equivalent to 6 pounds per head of the rations described in table 1. Treatments were started three weeks before breeding. With the onset of breeding, the feed allowed was increased to 6½ pounds per head per day.

[4] Also known as the **Hamprace.**

All groups had 15 percent wheat bran incorporated into their rations, just prior to and following parturition, and were fed according to appetite. The lactation ration contained 17 percent protein. Sows were reluctant to consume the dehydrated alfalfa pellets at first, but became accustomed to them during the first week and consumed them readily thereafter.

The birth weight, sex, and ear notch identification were recorded for each piglet, in most cases within 12 hours after birth and in all cases within 24 hours after the completion of farrowing.

TABLE 2. SUMMARY OF REPRODUCTIVE PERFORMANCE—1951

Ration	S. c. alfalfa No APF	S. c. alfalfa 0.5% APF	Dehy. alf. pellets No APF
No. of females available	16	16	16
No. of females conceived	14	14	15[1]
No. of females farrowed	14	13[2]	14
Av. number of pigs per litter	9.4	10.2	9.7
Av. no. live pigs per litter	8.5	9.5	8.4
Av. birth weight of pigs	3.1	2.8	2.8
Av. no. pigs weaned per sow	7.4	7.6	6.0**
Av. weaning weight per litter[3]	216	204	155**
Av. weaning weight per pig[3]	29	27	26
% pigs farrowed dead	10	7	14
% mortality to weaning of total number farrowed	22	25	38

[1] One pregnant gilt with nine fetuses died.
[2] Due to an error in estimated farrowing date one sow farrowed outside and lost all her pigs. The litter is not included in the above calculations.
[3] Average weaning weights corrected for age after the method of Whatley, *et al.* (1937).
** Significant at the 1% level.

In the first of the two trials described, the suckling pigs were creep fed rations similar to those being fed their dams. Feed was made available for the offspring at two weeks of age and until they were weaned.

Results and Discussion

A summary of the reproductive performance of the females on the different rations are given in table 2 for the spring farrow of 1951 and in table 3 for the spring farrow of 1952.

In lot 1, a Duroc sow and gilt were removed from the experiment after failing to conceive. In lot 2, a Duroc gilt and a Montana No. I

sow for the same reason. One Montana No. I sow, after being exposed to a Montana No. I boar, was removed from lot 3 for failure to conceive. The five animals that did not become pregnant represent matings by all four of the boars used. The failure to conceive then seems to be due the inherent lack of fertility of the individuals in question or purely to chance and not due to any particular sire or feeding regime. A Hamprace gilt farrowed her litter of nine pigs outside, because of an error in estimated farrowing date, and all the pigs died. Their loss was attributed to faulty management rather than to the effect of any experi-

TABLE 3. SUMMARY OF REPRODUCTIVE PERFORMANCE—1952[1]

Ration	S. c. alfalfa No APF	S. c. alfalfa 0.5% APF	Dehy. alf. pellets No APF
No. of females available	14	14	14
No. of females farrowed	11	11	12
Av. number of pigs per litter	9.7	8.5	10.4
Av. no live pigs per litter	8.7	7.8	9.1
Av. birth weight of pigs	2.8	2.9	2.5
Av. no. pigs weaned per sow[2]	7.3	5.9	5.7*
Av. weaning weight per litter[3]	158	146	124**
Av. weaning weight per pig[3]	22	25	22
% pigs farrowed dead	10	9	13
% mortality to weaning of total number farrowed	26	31	46

[1] The supervision of the work by Dr. O. O. Thomas and the gathering of the data by T. H. Hunter are acknowledged.

[2] Average number of pigs weaned per sow in lots 1 and 2 are based on 10 females in each lot due to a mistaken identity of litters.

[3] Average weaning weights corrected for age after the method of Whatley, *et al.* (1937).

* Significant at the 5% level.

** Significant at the 1% level.

mental treatment. In the calculations of all the criteria with the exception of the total number of pigs farrowed, 13 litters will be considered in lot 2. One gilt in lot 3 died of an undetermined cause.

Calculation of the least significant difference for the number of pigs weaned per sow showed a highly significant difference in favor of the group fed the basal ration over the group fed the dehydrated alfalfa pellets in the first year, and the difference was significant at the 5 percent level in the second year. In the first trial, the females on the basal diet weaned an average of 216 pounds of pig which was 6 percent more weight than the antibiotic fed females and 28 percent more weight than that weaned by the dehydrated alfalfa females. In the second trial, the same general relationship existed with the percentages being 8 percent

and 22 percent less for those animals fed the APF and the dehydrated alfalfa rations as compared with the basal. In both years these differences proved to be highly significant. The greatly reduced weight of pig weaned per sow by those females fed the dehydrated alfalfa ration as compared with those fed the basal ration is a result of fewer pigs being weaned per sow and a smaller average weaning weight of the individual pigs. The APF supplemented group weaned more pigs per sow but their average weight was less than those weaned by the basal group in the first year, whereas in the second year the average weaning weight of the pigs was greater than the basal group but there were fewer pigs weaned per sow.

It has been suggested that the feeding of dehydrated alfalfa in pellet form may have induced the older sows to sort and refuse the pellets, thus forcing the gilts to consume more than their share. This was not observed to be the case. Also, this does not seem likely in view of the fact that the first year the sows had the better reproductive record, whereas the second year the gilts performed better in reproduction.

The pigs born to those animals fed the basal diet were 0.3 pounds heavier on the average, in both years, than the offspring of the females on the dehydrated alfalfa ration. In the first year, the average birth weight of the pigs born from sows on the APF supplemented diet was 0.3 pounds less than those born of sows fed the basal diet; however, in the second year their birth weight averaged 0.1 pound more.

Of the total number farrowed, the mortality of pigs to weaning was 3 percent and 5 percent greater on the APF supplemented group than on the basal in the first and second years respectively. The extent to which this can be attributed to dietary regime, however, is questionable because there was actually 1 percent less pigs farrowed dead in both years, in the APF group. Of the total number farrowed, the mortality to weaning from sows fed the dehydrated alfalfa pellets in place of the sun-cured alfalfa meal was 16 percent higher in the first year and 20 percent higher in the second year. In both years there were approximately 4 percent more pigs farrowed dead by the females fed the dehydrated alfalfa pellets.

Conclusions

The addition of 0.5 percent APF-antibiotic supplement to a basal ration of barley, soybean oil meal, sun-cured alfalfa and meat meal for brood sows during pre-breeding, gestation and lactation resulted in no significant improvement with regard to number of pigs farrowed,

number of pigs farrowed alive, average birth weights and number of pigs weaned per sow.

A highly significant adverse result was obtained by substituting dehydrated alfalfa pellets for sun-cured alfalfa meal in the gestation-lactation ration as shown by the number of pigs weaned per sow and the total weight of pig weaned per sow. Of the total number of pigs farrowed, the percent mortality to weaning was 16 percent and 20 percent higher when dehydrated alfalfa pellets were fed in place of sun-cured alfalfa meal in the sows diet. In these trials, the extra cost of the dehydrated alfalfa combined with lower reproductive performance indicated that dehydrated alfalfa, in a pelleted form, was definitely inferior to sun-cured alfalfa meal as a feed component in rations for gestating-lactating sows and gilts.

Literature Cited

Anderson, G. C. 1949. The value of vitamin B_{12} for brood sows and weanling pigs. Progress Report 8, U. of Mo., Agr. Exp. Sta.

Catron, D. V. 1952. Antibiotics in swine nutrition. Proceedings of the Fourth Research Conference, American Meat Institute, Chicago, Illinois.

Catron, D. V., C. C. Culbertson, and P. S. Shearer. 1948. Studies on young pig mortality. JOURNAL OF ANIMAL SCIENCE 7:522 (abstract).

Carpenter, L. E. 1951. Effect of APF concentrate containing aureomycin on gestating, lactating and growing swine. JOURNAL OF ANIMAL SCIENCE 10:657.

Ensminger, M. E., R. W. Colby, and T. J. Cunha. 1951. Effect of certain B-complex vitamins on gestation and lactation in swine. Wash. Agr. Exp. Sta. Cir. No. 134.

Heidebrecht, A. A., O. B. Ross, R. W. MacVicar, and C. K. Whitehair. 1950. The effect of rations from plant sources on reproduction and lactation performance of sows. Okla. Agr. Exp. Sta. Misc. Pub. No. MP-17.

Krider, J. L., and W. E. Carroll. 1945. Effect of diet on gestation and lactation performance. JOURNAL OF ANIMAL SCIENCE 3:447.

Krider, J. L., B. W. Fairbanks, R. F. Van Poucke, D. E. Becker, and W. E. Carroll. 1946. Sardine condensed solubles and rye pasture for sows during gestation and lactation. JOURNAL OF ANIMAL SCIENCE 5:256.

Krider, J. L., D. E. Becker, W. E. Carroll, and B. W. Fairbanks. 1948. The value of dried fermentation solubles for sows fed in drylot during gestation and lactation. JOURNAL OF ANIMAL SCIENCE 7:332.

Snedecor, G. W. 1946. Statistical methods. 4th Ed. The Iowa State College Press, Ames, Iowa.

Whatley, J. A. Jr., and E. L. Quaife. 1937. Adjusting weights of pigs to a standard age of 56 days. Amer. Soc. Anim. Prod. Proc. 126.

RAISING BABY PIGS ON DRIED SKIM MILK: EFFECT OF THE ADDITION OF AUREOMYCIN AND OF LARD[1]

HAROLD E. SCHENDEL and B. CONNOR JOHNSON

University of Illinois

DRIED skim milk, reconstituted at levels ranging from 10 to 30 percent solids, with added minerals and vitamin A, has been reported by Green, *et al.* (1949), to be toxic to pigs 7 to 14 days old.

Wahlstrom and Johnson (1951), have reported the successful rearing of baby pigs on a "synthetic skim milk" containing 1 percent cottonseed oil on the dry basis.

Earlier short-term experiments seemed to indicate that skim milk might be an adequate diet for baby pigs. This was confirmed in this study in which the effect of the addition of aureomycin[2] and of 30 percent lard (on the dry basis) to a reconstituted powdered skim milk diet was also studied.

Experimental

Eighteen cross-bred pigs (New Hampshire x Poland China) obtained from a commercial pig hatchery were used in this experiment. The pigs were removed from their dams at 48 hours of age and housed individually in raised wire cages in a heated building.

The animals were divided into four groups, using a table of random numbers, and fed the following diets *ad libitum*. Group I (6 animals) received the skim milk basal ration (diet A, table 1); Group II (4 animals) received diet A plus 50 mg. aureomycin per kg. dry matter in the diet; and Group III (4 animals) received the skim milk with lard (diet B, table 2); and Group IV (4 animals) received diet B with 50 mg. aureomycin per kg. dry matter in the diet. The dried skim milk contained 0.46 percent fat on the dry basis.

The fat-soluble vitamins, the mineral solution and the aureomycin were added to the milk at the time of feeding. Feed consumption was recorded individually and the animals were weighed at weekly intervals.

Results and Discussion

The total performance of the animals is recorded in table 3.

The incidence of transmissible gastroenteritis presumably produced a

[1] This investigation was supported in part by funds donated by the Moorman Manufacturing Company, Quincy, Illinois.

[2] Aureomycin hydrachloride was generously supplied by the American Cyanamid Company, Pearl River, New York, through the courtesy of Dr. T. H. Jukes.

TABLE 1. COMPOSITION OF THE BASAL DIET

Ingredient	Ration A %	Ration B %
Dried non-fat milk solids[1]	100	70
Lard	...	30

These materials were made up, pasteurized and homogenized in the case of diet B, into a milk containing 19.5% solids. The following vitamins and mineral salts were added per liter and per day respectively.

Vitamin A	2000 I. U.	Ferric chloride	25 mg./day
Vitamin D	200 I. U.	Manganese sulfate	2.5 mg./day
Alpha-tocopherol acetate[2]	4 γ	Copper sulfate	2.5 mg./day
2-Methyl-1, 4-naphthoquinone	1 mg.		

[1] Dried skim milk was obtained from the Prairie Farms Creamery, Galesburg, Illinois.
[2] Alpha-tocopherol acetate was generously supplied by Merck and Company, Rahway, New Jersey, through the courtesy of Dr. Laurent Michaud.

39 percent mortality by the second week of the experiment. Four out of five animals in one of the litters died in a 12 hour period and were shown from the autopsies to demonstrate lesions characteristic of this disease. The three other animals which died also showed similar lesions on post mortem examination. The eighth animal excluded from the analysis gained only 2.19 kg. over the five week period and appeared to be in poor health throughout the experiment. This animal was sacrificed at the completion of the experiment and post mortem examination showed a diffuse peritonitis. Although these losses were sustained prior to the second week of the test, we continued the study since these losses were apparently not dietary in their etiology.

The statistical treatment of these data included an analysis of covari-

TABLE 2. AVERAGE PERFORMANCE[1] OF THE BABY PIGS ON THE SKIM MILK DIET

Treatment	Number of Animals	Average Total Gain (5 weeks) Kg.	Kg. Dry Matter Consumed per Kg. Gain
Effect of Fat:			
Without Fat	7	6.65	2.87
With Fat	3	7.18[2]	1.31
Effect of Aureomycin:			
Without Aureomycin	3	6.54	2.17
With Aureomycin	7	7.43[2]	2.50

[1] These data are unadjusted for variation in initial weight and feed consumption.
[2] These differences are not statistically significant.

TABLE 3. EFFECT OF AUREOMYCIN AND LARD ON BABY PIGS FED A SKIM MILK DIET

Pig	Fat	Aureomycin	Initial Weight Kg.	Feed Consumption Kg. D.M.	Final Weight Kg.		Efficiency Ratio Kg. D.M./Kg. Gain
					Observed	Adjusted[1]	
1	—	—	1.31	15.05	5.40	6.13	3.68
2	—	—	1.27	19.60	7.19	6.39	3.31
3	—	—	2.10	24.43	11.18	7.76	2.69
4	—	—	2.24	20.85	9.58	7.87	2.84
5	—	—	1.25	16.89	9.07	8.91	2.16
6	+	—	2.11	7.81	6.73	9.13	1.69
7	+	—	1.46	8.04	8.39	10.74	1.16
8[2]	—	+	1.39		3.58		
9	—	+	1.17	10.53	5.33	8.01	2.53
10	—	+	2.30	23.61	10.44	7.21	2.90
11	+	+	1.95	10.80	11.95	13.10	1.08

[1] Values adjusted for variation in feed consumption.
[2] Animal excluded from the analysis.

ance using regression equations of final weight on initial weight and feed consumption.

The effect of initial weight variation on feed consumption and final weight was found to be without significance. Feed consumption, however, was shown to exert a highly significant effect on final weight ($p=0.007$).

The effect of variation in initial weight, the effect of aureomycin and the aureomycin-fat interaction were all shown to be without significance. However, fat affected feed consumption as much as 7.62 kg. (95 percent confidence level) which was highly significant ($p=0.015$).

The treatment effects were without significance both on the observed final weight and final weight adjusted for variation in initial weight. But treatment effects on final weight adjusted for feed consumption were shown to be significant and as great as 3.52 kg. (95 percent confidence level). The presence of fat in particular exerted a highly significant effect ($p=0.017$).

From the ten animals which finished the test, we were able to conclude that the baby pig is able to gain "normally" on a reconstituted skim milk diet.

Summary

When supplemented with vitamins A, D, E, and K, as well as the minerals iron, copper and manganese, the baby pig is able to gain "normally" on a skim milk diet. As would be expected the presence of 30 percent fat markedly improved the feed efficiency ratios due to its much higher energy content per gram.

Literature Cited

Green, W. W., H. C. H. Kernkamp, M. H. Roepke and L. M. Winters. 1949. A toxemic-uremic syndrome in baby pigs fed on dried skimmilk. Am. Jour. Vet. Res. 10:256.

Wahlstrom, R. C. and B. Connor Johnson. 1951. Effect of cortisone and of aureomycin on baby pigs fed a vitamin B_{12} deficient diet. Proc. Soc. Exptl. Biol. Med. 78:112.

COMPARISON OF ANTI-BACTERIAL AND ANTI-YEAST-MOLD ANTIBIOTICS WITH BABY PIGS IN THE PRESENCE OF SEVERAL LEVELS OF B VITAMINS[1]

HAROLD E. SCHENDEL and B. CONNOR JOHNSON[2]

University of Illinois

SINCE the report by Stokstad and Jukes (1948) that a fermentation supplement derived from *Staphylococcus aureofaciens* stimulated growth to a greater extent than did crystalline vitamin B_{12}, there has been an extensive study of the comparative stimulatory effects of many antibiotics.

The effect of terramycin on the cecal and fecal micro-flora of turkeys has been reported by Sieburth, Gutierrez and McGinnis (1951) and on fecal micro-flora of pigs by Cuff, Maddock, Speer and Catron (1951). The microbial inhibition, however, was not shown to be consistent with the effect on growth. Terramycin has also been shown to be a very effective antibiotic: improving feed efficiency of chicks and poults (Briggs and Davis, 1951), and being the most potent growth stimulant of 5 antibiotics tested with poults on an animal protein diet (Branion and Hill, 1951).

Since terramycin acts as an anti-bacterial agent (Hobby, Lenert, Pikula, *et al.*, 1950), it appeared desirable to compare it with rimocidin, an antibiotic effective against yeasts and molds and reported to have produced a 51 percent increase in rate of growth in hogs at 8 weeks (Luther and Brown, 1951). In the experiment reported here, comparison is made between terramycin and rimocidin, both bacteriologically and as to the extent of growth stimulation, with baby pigs fed a "synthetic milk" and two levels of vitamins. The bacteriological aspects of this study will be reported later.

Experimental

Sixteen baby pigs (8 Duroc-Jersey, 4 Chester White, 4 Hampshire x Duroc-Jersey) obtained from the University Swine Farm and a commercial pig hatchery were removed from their dams at 48 to 96 hours

[1] This investigation was supported in part by funds donated by the Moorman Manufacturing Company, Quincy, Illinois.

[2] Grateful acknowledgment is made of the assistance of Dr. H. W. Norton, Professor of Agricultural Statistics, in the statistical treatment of the data.

of age and assigned at random to 8 treatment groups. The design used was a 2^3 factorial design, the three factors being level of B vitamin supplementation and the presence or absence of terramycin and of rimocidin. The animals were maintained throughout the experimental

TABLE 1. COMPOSITION OF THE BASAL DIET

Constituents[1]	Percent (Dry Basis)
Alpha protein (isolated soybean protein)[2]	29.4
DL-Methionine	0.6
Sucrose	30.9
Lard	30.8
Mineral salts[3]	8.3
Water Soluble Vitamins:	**Per Liter Milk**
Thiamine[4]	0.65 mg.
Riboflavin	1.30 mg.
Calcium pantothenate	7.80 mg.
Nicotinic acid	2.67 mg.
Pyridoxine hydrachloride	1.30 mg.
Choline chloride	130.00 mg.
P-amino benzoic acid	2.60 mg.
Pteroylglutamic acid	0.052 mg.
Ascorbic acid	16.00 mg.
Biotin	0.01 mg.
Inositol	
Fat Soluble Vitamins:	
Vitamin A	2000 I.U.
Vitamin D	200 I.U.
Alpha-Tocopherol acetate	1.00 mg.
2-methyl-1, 4-naphthoquinone	0.26 mg.

[1] These constituents were homogenized into a "synthetic milk" containing 19.5 percent solids and 6 percent fat.

[2] Alpha-protein was obtained from the Glidden Company, Chicago, Illinois.

[3] For composition of mineral mixture, see Johnson, James and Krider (1948).

[4] Thiamine hydrachloride, riboflavin, pyridoxine hydrachloride, calcium pantothenate, biotin, nicotinic acid, ascorbic acid and alpha-tocopherol acetate were generously supplied by Merck and Company, Rahway, New Jersey, through the courtesy of Dr. Laurent Michaud. Pteroylglutamic acid was supplied by the American Cyanamid Company, Pearl River, New York, through the courtesy of Dr. T. H. Jukes. Inositol was supplied by the A. E. Staley Manufacturing Company, Decatur, Illinois. Methionine was generously supplied by Dow Chemical Company, Midland, Michigan, through the courtesy of Dr. Julius Johnson. Sulfathalidine (Phthalylsulfathiazole) was generously supplied by Sharp and Dohme, Inc., Philadelphia, Pennsylvania, through the courtesy of Dr. S. F. Scheidy.

period in raised, wire-bottom cages and fed *ad libitum*. Individual feed consumption and weight records were kept throughout the experiment.

The composition of the alpha-protein "synthetic milk" ration is shown in table 1. This milk was made up to contain 19.5 percent solids as described by Neumann, Thiersch, *et al.* (1950). The water

soluble vitamins were administered in a 30 percent ethanol solution at the time of feeding. Eight of the animals received these vitamins at the level used previously in this laboratory (Neumann, Krider and Johnson, 1948). The 8 remaining animals received a level of B vitamins 5 times this amount. In addition to the vitamin supplement added to the diet, vitamin B_{12} was administered once a week intramuscularly at a level of 0.8 gamma per kg. body weight per day (Nesheim, Krider and Johnson, 1950).

In addition to these water soluble vitamins, 2000 I. U. vitamin A, 200 I.U. vitamin D, 1 mg. alpha-tocopherol acetate, and 0.26 mg. 2-methyl-1, 4-naphthoquinone were fed per liter of "synthetic milk". Sulfathalidine was also added at the rate of 2 gm. per liter of milk in an effort to control scouring. The method of feeding and care of baby pigs in this laboratory has been reported previously (Johnson, James and Krider, 1948).

TABLE 2. PERFORMANCE[1] OF BABY PIGS ON ANTIBIOTICS AND TWO LEVELS OF B VITAMINS

Treatment	Number of Animals	Average Total Gain (5 weeks) Kg.	Kg. Dry Matter Consumed per Kg. Gain
Effect of Terramycin			
With Terramycin	7	15.14	1.43
Without Terramycin	7	7.31	2.17
Effect of Rimocidin			
With Rimocidin	8	10.97	1.87
Without Rimocidin	6	11.56	1.71
Effect of B Vitamins			
Optimal B Vitamins	7	11.74	1.88
Excessive B Vitamins	7	10.71	1.72

[1] The data recorded here are the observed weight gains and feed consumption with no adjustment for variation in initial weight, age, source, or feed consumption.

The antibiotics were added to the milk at the time of feeding at the level of 50 mg. per kg. dry matter of the diet.

As the animals reached 5 weeks of age they were sacrificed and the micro-flora of the cecum and small intestine were studied bacteriologically.

Results

The performance of the animals is summarized in table 2. Although 16 pigs began the experiment, one animal on the basal diet died in the

second week and was not replaced. Another animal, receiving terramycin and the higher level of B vitamins, is also excluded from the table and analysis since he showed an extreme dermatitis and irritability throughout the experiment and gained only 0.18 kg. per day. The remaining animals which died were replaced and this different source was shown not to exert a significant effect on the final outcome of the experiment.

The statistical analysis of these data was carried out by the method of fitting constants. The variables which were included in the analysis are the following: terramycin, rimocidin, level of B vitamins, feed consumption, initial weight variation, initial age variation, and source of animals.

There was no statistically significant interaction of the three treatments, and none of the seven variables exerted a significant effect on the final weight except terramycin and feed consumption with respective P values of 0.038 and <0.001. The effect of terramycin on final weight after equalization of feed consumption ($P<0.05$) suggests this antibiotic exerts an effect of from 0.24 to 6.06 kg. over a five week period in addition to any effect of increasing feed consumption. The efficiency ratio of food consumption to weight gain in the terramycin group is 1.43 as compared to 2.17 in those animals not receiving terramycin (note table 2). The effect of rimocidin, two levels of B vitamins, the initial variation in weight and age as well as the source of animals on final weight was not found to be significant.

In order to determine whether any of the 7 previously mentioned variables had an effect on feed consumption, a second series of analyses was performed. In this analysis it was found that the source alone had an effect ($P<0.05$): more specifically, the University animals consumed more feed. The effect of terramycin on feed consumption approached significance ($P=0.10$).

Discussion

In order to learn more about the interrelationship of antibiotics and the B vitamins (Lih and Bauman, 1951) (Sauberlich, 1952) and something about the mode of action of antibiotics in an animal, we supplemented the diets of half of the experimental animals with a level of B vitamins which was 5 times the level used previously in this laboratory. In the past, using this lower level of vitamin supplementation which we believe to be adequate nutritionally, we have been able to demonstrate growth stimulation with several antibiotics (Nesheim and Johnson, 1950) (Wahlstrom, Terrill and Johnson, 1950) (Wahlstrom

TABLE 3. EFFECT OF TERRAMYCIN AND RIMOCIDIN ON BABY PIGS IN THE PRESENCE OF SEVERAL LEVELS OF B VITAMINS

Pig	Source	Age Days[1]	B Vitamins	Terramycin	Rimocidin	Initial Weight Kg.	Feed Consumption Kg. D.M.	Final Weight Kg. Observed	Final Weight Kg. Adjusted[2]	Efficiency Ratio Kg. D.M./ Kg. Gain
1	U	10	N	—	—	2.10	23.41	14.30	14.46	1.86
2[3]	U		N	—	—	1.33	Died on the eleventh day of the experiment			
3	U	9	N	+	—	2.91	22.78	18.25	17.91	1.40
4	C	7	N	+	—	1.23	18.37	12.63	12.22	1.61
5	C	10	N	—	+	1.45	15.88	7.60	8.02	2.59
6	C	7	N	—	+	1.22	8.49	4.11	5.02	2.94
7	U	10	N	+	+	2.50	22.08	19.95	17.98	1.24
8	U	12	N	+	+	2.43	23.39	16.84	17.54	1.55
9	C	6	E	—	—	1.83	17.10	12.13	11.03	1.64
10	C	8	E	—	—	1.27	9.39	5.84	4.63	2.12
11	U	9	E	+	—	2.29	22.71	15.74	17.01	1.61
12[3]	U		E	+	—	1.51	13.95	9.26	.....	1.80
13	C	7	E	—	+	1.23	10.82	5.64	7.04	2.45
14	U	10	E	—	+	1.56	16.10	11.72	10.05	1.58
15	U	10	E	+	+	1.79	19.54	16.92	12.01	1.27
16	U	9	E	+	+	1.69	21.93	17.86	16.74	1.35

[1] Days of age when animal was assigned to the treatment.
[2] Values adjusted for variation in feed consumption.
[3] Animal excluded from the analysis.
U=University Swine Farm.
C=Commercial Pig Hatchery.
N=Normal Level.
E=Excessive Level.

and Johnson, 1951). It appeared conceivable that at this higher level of vitamin supplementation the antibiotics studied would be incapable of exerting a growth response. However, from the statistical analysis of the data it was evident that the level of B vitamins did not exert a significant effect on final weight in the presence of terramycin or rimocidin.

Since it has been suggested several times that the antibiotic stimulus on growth is manifested through an effect on feed consumption, we included food intake in the statistical analysis. Although measurement is difficult when feeding a liquid diet to baby pigs, nevertheless food intake data proved valuable in the analysis of final weights, reducing the error mean square from 10.31 to 2.87.

The only variable having an effect on final weight, terramycin, did not have a statistically significant effect on food consumption. Therefore, we may conclude that terramycin may have exerted its effect in part at least through some mechanism other than increasing the level of known B vitamins in the gut or stimulating food consumption.

In an effort to explain partially the remarkable effect which terramycin seemed to exert in this experiment, we suggest that it acted here as a prophylactic agent against transmissible gastroenteritis. Unfortunately this disease was introduced apparently, into our experimental herd by one litter of piglets. Four out of 5 animals in this litter died and were reported to show evidence of gastroenteritis on autopsy. According to the autopsies on the 13 animals which we lost, 9 of those apparently died of transmissible gastroenteritis. All of these animals died prior to the second week of the experiment which corresponds to the period when the piglet is most susceptible to this disease. However, in only one case did an animal receiving terramycin die and this occurred in an especially weak animal weighing only 0.79 kg. at 3 days of age.

Therefore, we suggest that terramycin in this experiment exerted part of its effect on growth by preventing the precipitation of transmissible gastroenteritis. However, the effect of terramycin on growth rate continued throughout the experiment as can be seen in figure 1.

Summary

Terramycin exerted a significant effect on the final weight of baby pigs fed a "synthetic milk" in the presence of two levels of B vitamins. This effect was significant after the variation in feed consumption was equalized.

The effect of rimocidin on final weight was not found to be significant. No imposed treatment, with exception of the source of baby pigs, had a significant effect on the feed consumption.

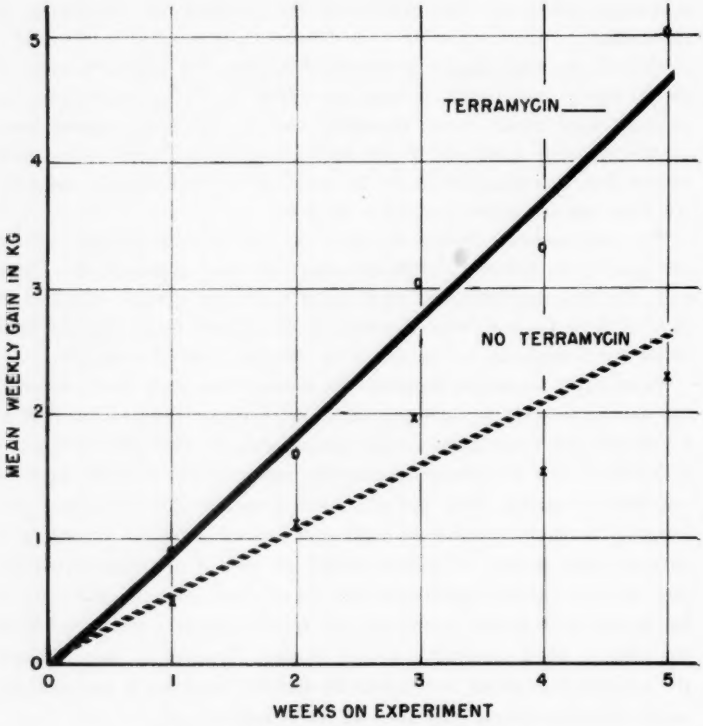


Figure 1. Mean weekly gain of baby pigs.

Literature Cited

Branion, H. D. and D. C. Hill. 1951. Comparative effect of antibiotics on growth of poults. Poul. Sci. 30:793.

Cuff, P. W. W., H. M. Maddock, V. C. Speer and D. V. Catron. 1951. Effect of different antibiotics on growing-fattening swine. Iowa State College Journal of Science 25:575.

Davis, R. L. and G. M. Briggs. 1951. Studies with antibiotics in chick and poult starting rations. Poul. Sci. 30:767.

Hobby, Gladys L., Tulita F. Lenert, Doria Pikula, Mary Kiseluk and M. Elizabeth Hudders. 1950. The antimicrobial action of terramycin. Annals of the N. Y. Acad. of Sci. 53:266.

Johnson, B. Connor, M. F. James and J. L. Krider. 1948. Raising newborn pigs to weaning age on a synthetic diet, with attempt to produce a pterolyglutamic acid deficiency. JOURNAL OF ANIMAL SCIENCE 7:486.

Lih, Hwa and C. A. Bauman. 1951. Effects of certain antibiotics on the growth of rats fed diets limiting in thiamine. Jour. Nutr. 45:143.

Luther, H. G. and J. H. Brown. 1951. Antibiotics in ration of hogs—effect of withdrawal and long term feeding, levels and comparison of antibiotics including anti-fungal type. JOURNAL OF ANIMAL SCIENCE 10:1055.

Nesheim, R. O. and B. Connor Johnson. 1950. Response of pigs to streptomycin. Proc. Soc. Exp. Biol. Med. 75:709.

Nesheim, R. O., J. L. Krider and B. Connor Johnson. 1950. The quantitative crystalline vitamin B_{12} requirement of the baby pig. Arch. Biochem. 27:240.

Neumann, A. L., J. L. Krider and B. Connor Johnson. 1948. Unidentified growth factors needed for optimal growth of newborn pigs. Proc. Soc. Exp. Biol. Med. 69:513.

Neumann, A. L., J. B. Thiersch, J. L. Krider, M. F. James and B. Connor Johnson. 1950. Requirements of the baby pig for vitamin B_{12} fed as a concentrate. JOURNAL OF ANIMAL SCIENCE 9:83.

Sauberlich, H. E. 1952. Effect of aureomycin and penicillin upon the vitamin requirements of the rat. Jour. Nutr. 46:99.

Sieburth, J. M., J. Gutierrez, J. McGinnis, J. R. Stern and B. H. Schneider. 1951. Effect of antibiotics on intestinal micro flora and in growth of turkeys and pigs. Proc. Soc. Exp. Biol. Med. 76:15.

Stokstad, E. L. R., A. Page and T. H. Jukes. 1948. Activity of microbiological animal protein factor concentrates in pernicious anemia. J. Lab. Clin. Med. 33:860.

Wahlstrom, R. C. and B. Connor Johnson. 1951. Effect of cortisone and of aureomycin on baby pigs fed a vitamin B_{12} deficient diet. Proc. Soc. Exp. Biol. Med. 78:112.

Wahlstrom, R. C., S. W. Terrill and B. Connor Johnson. 1950. Effect of antibacterial agents on growth of baby pigs fed a synthetic diet. Proc. Soc. Exp. Biol. Med. 75:710.

PENICILLIN AND STREPTOMYCIN AFFECT THE MICROFLORA OF THE INTESTINAL TRACT OF PIGS

J. H. BRIDGES,[1] I. A. DYER, and J. J. POWERS

University of Georgia[2]

IT is generally accepted that certain antibiotics stimulate growth in swine and poultry. Furthermore, many data have been published which indicate that the mode of action of antibiotics in stimulating growth is either directly or indirectly associated with the microflora in the intestinal tract of the host.

Luckey (1952) reported that germ-free chicks did not favorably respond to either streptomycin, sulfasuxidine, chloromycetin, bacitracin, terramycin or penicillin whereas conventional birds gave a positive growth response when these antibiotics were fed. From these results he implied that antibiotics effect a growth response in conventional birds by acting upon some system connected either directly or indirectly to the microflora of the host. McGinnis (1950) stated that growth acceleration, when antibiotics are fed, might be a result of either: (1) reduction in total number of bacteria in the intestinal tract, (2) synthesis of vitamins by bacteria; (3) the inhibition of either pathogenic or toxin producing bacteria. Groschke (1950) suggested that antibiotics stimulate growth in chicks by changing the intestinal microflora from undesirable to desirable types of bacteria.

Couch *et al.* (1950) reported an increase in total count of bacteria in feces of chicks when penicillin was included in the ration. The same was reported for pigs when penicillin was fed (Bridges *et al.* 1952). According to Sieburth *et al.* (1951) it appears that not only the total number of bacteria but also the number of bacterial types found in the fecal contents is influenced by the antibiotic supplements.

Wahlstrom *et al.* (1950) reported that penicillin had no significant effect on the number of coliform bacteria present in the feces of baby pigs fed a "synthetic" milk diet.

Bridges *et al.* (1952) reported a significant increase in bacterial count in feces of pigs when penicillin was added to a corn-degossypolized

[1] Conducted in partial fulfillment of the requirements for the degree of Master of Science in Agriculture.

[2] The authors are appreciative of the cooperation of: Dr. Kenneth Kuiken, The Buckeye Cotton Oil Co., Cincinnati, O., for supplying the cottonseed and soybean oil meals; Dr. L. Michaud, Merck and Co., Inc., Rahway, N. J., for contributing penicillin, streptomycin and vitamins B_1, B_2, niacinamide, calcium pantothenate and B_{12}; and Mr. Vernon Dawe, Dawe's Manufacturing Co., Chicago, Ill., for providing vitamins A, D and choline chloride for this experiment.

cottonseed meal ration. However, the addition of streptomycin or a combination of penicillin and streptomycin did not significantly increase total bacterial count.

Many conflicting reports concerning the efficacy of antibiotics in accelerating growth have been published. These reports can be reconciled, at least partially, by noting that the response to antibiotics apparently varies with a number of factors; namely, the environment, type of animal, the amount and kind of antibiotic as well as the method of administration, the particular dietary protein with which they are fed and the levels of protein and vitamins in the diet to which the animal is subjected. Presumably the above conditions alter the microflora in the intestinal tract of the pig.

The objectives of this test were: 1. To study possible effects of penicillin, streptomycin and a combination of penicillin and streptomycin on the growth rate, feed efficiency and the microflora of the intestinal tract of the pig. 2. To determine the most prevalent bacteria in the feces of pigs. 3. To determine if a significant correlation exists between any of the more prevalent groups of bacteria and rate of gain made by the pigs and 4. To determine whether a significant correlation exists between fecal dry matter and the bacterial count.

Experimental Procedure

Four groups of 3 Duroc-Poland China cross-bred pigs each were used in this experiment. Pigs that had been in drylot since birth were allotted on the basis of weight, sex, litter and condition after a 7-day preliminary period. All pigs were housed in comparable concrete-floored pens, bedded with wood shavings and given free access to water. They were self-fed a 20 percent crude protein corn-degossypolized cottonseed meal ration fortified with minerals and vitamins.

Fecal samples were collected from all pigs at the end of the 7-day preliminary period during which all pigs were fed the same basal ration. Thereafter, pigs were weighed and samples collected weekly until 9 samples from each pig had been collected.

The following media were used in isolating bacteria: Difco Bacto Violet Red Bile Agar to identify the coliform group of bacteria, Bacto Staphylococcus Medium 110 for the Staphylococcus genus, Bacto Urea Agar for the Proteus genus, Bacto SS Agar for the Shigella and Salmonella genera, Brilliant Green Agar to separate the Shigella from the Salmonella. The technique used was as outlined by Difco Manual (1948).

At regular intervals a slide was made from different colonies on the dish and examined microscopically to ascertain that the correct bacteria were being counted.

For a determination of fecal dry matter, a 2 to 5 gram sample of feces from each of the samples collected was weighed in aluminum dishes with covers. The procedure as recommended by the A.O.A.C. (1945) for determination of dry matter was followed. Data were analyzed by analysis of variance.

Results and Discussion

The effects of adding penicillin and streptomycin to a corn-degossypolized cottonseed meal ration fortified with minerals and vitamins for weanling pigs in drylot are presented in table 1. Pigs fed the basal ration (lot 1) made an average daily gain of 1.23 ± 0.06 lb., whereas, when penicillin was included (lot 2) the average daily gain was 1.46 ± 0.13 lb. The average daily gain of pigs fed streptomycin (lot 3) was $1.39 \pm .02$ lbs.

The mean gain of pigs in groups 2 and 3 (penicillin, 2.27 mg. per lb. of feed and streptomycin, 2.50 mg. per lb. respectively) was greater than that made by pigs fed the basal ration. However, differences in the average daily gains of either groups 1, 2 or 3 were not significant. A combination of penicillin and streptomycin (lot 4) added to the ration at the same levels as indicated above, resulted in a significantly faster ($1.54 \pm .04$ lbs.) rate of gain than that made by either group 1 or 3. Feed efficiency was quite similar although the daily feed consumption was considerably higher in the groups fed antibiotics as will be observed from table 1.

The addition of penicillin to the basal ration resulted in a significant increase in the coliform group of bacteria, whereas, streptomycin had little effect on this group. A combination of penicillin and streptomycin not only had a stimulating effect on the rate of gain but also on the number of coliform bacteria. This increase in coliform bacteria was of essentially the same magnitude as when penicillin alone was fed. These results are not in agreement with those obtained by Wahlstrom *et al.* (1950). However, it must be kept in mind that they fed approximately 20 times as much penicillin, used baby pigs instead of weanling pigs and the diets were different from those used in the experiment reported here.

The effect of penicillin on the coliform group of bacteria *in vivo* has not been definitely determined. However, the resistance (*in vitro*) of

TABLE 1. EFFECT OF PENICILLIN AND STREPTOMYCIN ON GROWTH RATE AND THE MICROFLORA OF THE INTESTINAL TRACT OF PIGS

Item	Lot Numbers and Treatments			
	1	2	3	4
	63% corn, 35% degossypolized cottonseed meal,[1] 2% mineral mixture and vitamins[2]	Same as lot 1 plus 227 mg. procaine penicillin G per 100 lbs. feed	Same as lot 1 plus 250 mg. streptomycin per 100 lbs. feed	Same as lot 3 plus 227 mg. procaine penicillin G per 100 lbs. feed
No. of pigs	3	3	3	3
Av. initial weight, lb.	48	46	48	49
Av. final weight, lbs.	118	129	127	137
Av. days on test	57	57	57	57
Av. daily gain, lbs. and standard error	1.23 ± .06	1.46 ± .13	1.39 ± .02	1.54*[a] ± .04
Av. daily feed/pig, lbs.	4.71	5.02	5.89	6.14
Feed/100 lb. gain, lb.	384	345	425	398
No. of fecal samples/pig	9	9	9	9
Av. No. of Bacteria—1,000,000/g. feces[3]				
coliform	1	101	3	127
Staphylococcus	48	39	43	46
Shigella	39	37	7	100
Proteus	37	68	72	204
Av. D.M. in feces, %	69.3	72.8	71.8	70.4
Correlation between rates of gain and No. of:				
coliform	—.028	.631**	.043	—.103
Staphylococcus	.008	—.035	.317	.199
Shigella	.256	.506*	—.061	—.002
Proteus	—.411	.427	.107	.198

[a] Pigs gained faster than pigs in lots 1 and 3.
* $P<0.05$.
** $P<0.01$.
[1] Contained less than .03% free gossypol.

[2] Vitamin additions to the 20% crude protein ration were: 500 I.U. vitamin A; 100 I.U. vitamin D; 0.5 mg. thiamine; 1.0 mg. riboflavin; 2.0 mg. niacinamide; 5.0 mg. calcium pantothenate; 250 mg. choline chloride and 7.5 mcg. B_{12} per lb.
[3] For the isolation of bacteria the following were used: Bacto Violet Red Bile Agar (coliform); Bacto Staphylococcus Medium 110 (Staphylococcus); Bacto SS Agar (Shigella and Salmonella); Bacto Brilliant Green Agar (Salmonella); Bacto Urea Agar Base (Proteus).

these bacteria to penicillin does not explain their increase in the feces.

The inclusion of penicillin, streptomycin or a combination of penicillin and streptomycin had no significant effect on the Staphylococcus genus.

When penicillin and streptomycin were fed singly, the average Proteus counts were 68 and 72 million per gram respectively, as compared with 37 million for pigs fed the basal ration. These differences were not statistically significant. A combination of penicillin and streptomycin resulted in a highly significant increase in the number of Proteus bacteria (204 million per gram). It appears that a synergistic effect occurs when a combination of penicillin and streptomycin is fed.

The number of Shigella in the feces of pigs was not significantly influenced by the treatments in this test.

The difficulty of estimating or predicting the intestinal flora in pigs fed antibiotics became more and more apparent as the experiment progressed. There was considerable variation in the numbers of bacteria present within treatments.

Correlation and regression coefficients were calculated on average bacterial count and average rates of gain. The addition of penicillin to the basal ration (group 2) resulted in a highly significant correlation between the coliform bacteria and rates of gain, although no significant correlation existed between rates of gain and either the Shigella, Proteus or Staphylococcus count in the feces.

There was no significant correlation between fecal dry matter and total bacterial counts in either groups 1, 2 or 3, but a significant correlation existed in group 4 (combination of penicillin and streptomycin).

It is possible that penicillin retarded the growth of some organisms which normally are antagonistic toward coliform bacteria or that penicillin might simply retard some organism which normally competes with coliform bacteria for certain nutrients. Another possibility is that penicillin might change the oxidation and reduction state of intestinal contents by altering the intestinal flora.

Summary and Conclusions

One experiment is reported in which penicillin and streptomycin, singly and in combination, were added to a corn-degossypolized cottonseed meal ration for pigs. Neither penicillin nor streptomycin significantly increased growth rate when fed singly. However, a combination of penicillin and streptomycin produced a significantly faster rate of gain than either the basal ration or the basal ration plus streptomycin.

The inclusion of penicillin or a combination of penicillin and strepto-

mycin significantly increased the coliform bacterial count in the feces of the pigs. Likewise a combination of penicillin and streptomycin significantly increased the Proteus count over the basal group.

The four most prevalent groups of bacteria in the intestinal tract of these pigs were coliform, Shigella, Proteus and Staphylococcus.

A significant correlation existed between rates of gain and the coliform group of bacteria when penicillin was fed.

A significant correlation existed between fecal dry matter and total bacterial count when a combination of penicillin and streptomycin was fed.

Literature Cited

Bridges, J. H., I. A. Dyer, W. C. Burkhart and A. E. Cullison, 1952. Effects of penicillin and streptomycin on the growth rate and bacterial count in the feces of pigs. JOURNAL OF ANIMAL SCIENCE 11:474.

Couch, J. R., J. F. Elam and L. L. Gee. 1951. Effect of penicillin on growth, egg production and hatchability. Fed. Prod. 10:379.

Difco Manual (1948). Difco Laboratories, Inc., Detroit, Mich.

Fisher, H. J., L. E. Warren, J. W. Sole, W. H. Ross, W. F. Reindollar and M. L. Otis. 1945. Methods of Analysis of Association of Official Agricultural Chemists.

Groschke, A. C. 1950. Relation of growth stimulating properties of antibiotics to unidentified growth factors required by the chick. Poul. Sci. 29:760.

Luckey, Thomas D. 1952. Effect of feeding antibiotics upon the growth rate of germ-free birds. A Colloquim LOBUND Institute. University of Notre Dame, Notre Dame, Ind.

March, B. and Jacob Biely. 1952. The effect of feeding aureomycin on the bacterial content of chick feces. Poul. Sci. 31:177.

McGinnis, J. 1950. Antibiotics as growth stimulants for chick and turkey poults. Proc. of the 1950 Cornell Nutrition Conference for Feed Manufacturers. 40.

Sieburth, John McN., Jose Gutierrez, James McGinnis, Joel R. Stern and B. H. Schneider. 1951. Effects of antibiotics on intestinal microflora and on growth of turkeys and pigs. Proc. Soc. Exptl. Biol. and Med. 76:15.

Wahlstrom, R. C., S. W. Terrill and B. Connor Johnson. 1950. Effect of antibacterial agents on growth of baby pigs fed a "synthetic" diet. Proc. Soc. Exptl. Biol. and Med. 75:710.

SUPPLEMENTATION OF A CORN-MEAT AND BONE SCRAP RATION FOR WEANLING PIGS[1]

R. E. Bloss,[2] R. W. Luecke, J. A. Hoefer, F. Thorp, Jr. and W. N. McMillen[3]

Michigan Agricultural Experiment Station[4]

THE routine analysis of various feed ingredients in swine rations has shown that meat and bone scraps are variable in their content of the amino acid tryptophan. It was frequently found that samples of meat and bone scraps were too low in tryptophan to make an adequate supplement to corn when fed to growing pigs. The poor growth sometimes observed in growing pigs fed a corn-meat scrap ration may be explained on this basis.

As early as 1935, Almquist *et al.* found that meat scrap gave unsatisfactory results when used as a protein supplement in chick rations. However, these workers stated that the cystine and tryptophan content of the animal protein concentrates could not be used to predict their nutritive values. Kraybill and Wilder (1947) carried out investigations which indicated that some samples of meat scrap may be deficient in methionine and tryptophan. Using swine type rations Kraybill (1947) fed different samples of meat scrap to rats and concluded that the growth response was related to the tryptophan content of the meat scrap; however, this was not found to be true with chicks. March, Stupich and Biely (1949) indicated that there was considerable variation in meat meals. The relatively low nutritive value of meat meal protein, when compared with fish meal, was considered to be partly the result of deficiencies of tryptophan or methionine or a combination of these amino acids. More recently, March, Biely and Young (1950) fed meat scrap as the only source of animal protein to chicks and observed no correlation between the amino acid content of the meat scrap and the growth response.

[1] Published with the approval of the Director of the Michigan Agricultural Experiment Station as Journal Article No. 1409.

[2] The data contained in this paper are a portion of the research and thesis to be presented by the senior author in partial fulfillment of the requirements for the Degree of Doctor of Philosophy, School of Graduate Studies, Michigan State College, East Lansing. Present address Larro Research Farm, Detroit, Michigan.

[3] Present address A. E. Staley Mfg. Co., Decatur, Illinois.

[4] Departments of Animal Husbandry, Agricultural Chemistry and Animal Pathology, Michigan State College, East Lansing. The authors are indebted to Lederle Laboratories Division, American Cyanamid Co., Pearl River, New York for the aureomycin and B vitamins, and to the Dow Chemical Company, Midland, Michigan for the DL tryptophan. This work was supported in part by a grant from Central Soya Company, Inc., Fort Wayne, Indiana.

Beeson *et al.* (1949) using a tryptophan deficient purified ration showed that tryptophan was an essential amino acid for the weanling pig. Shelton, Beeson and Mertz (1951) observed that a level of 0.2 percent of DL-tryptophan, when added to a tryptophan deficient purified diet containing 24.5 percent protein and adequate niacin, supported maximum growth under the conditions of the experiment.

In view of the results obtained with chicks and rats, it therefore seemed advisable to determine if tryptophan added to a corn-meat scrap ration would improve the nutritive value for swine. Since soybean oil

TABLE 1. RATIONS

Ingredient	Percentage			
	A	B	C	D
Ground Corn	78.5	75.8	73.0	79.7
Meat & Bone Scrap (50%)[1]	20.0	11.0	....	20.0
Soybean Oil Meal (44%)	....	11.0	24.0	....
Limestone	0.4	0.4	0.5	....
Dicalcium Phosphate	0.5	1.0	1.5	....
Iodized Salt	0.5	0.7	0.9	0.2
Trace Mineral	0.1	0.1	0.1	0.1
Tryptophan[2]	0.09	0.13	0.16	0.08

All rations were supplemented with pantothenic acid, niacin, riboflavin and vitamin B_{12} in amounts of 10 mg., 15 mg., 2 mg. and 6.25 respectively per pound of feed. Ample amounts of vitamins A and D were also added to all rations.

[1] The Meat and Bone scrap used in ration D was a composite of four different brands in equal amounts.

[2] As determined by microbiological analysis.

meal is a good source of tryptophan it also seemed desirable to use a corn-soybean oil meal ration as a standard of comparison.

Cunha and coworkers (1949) reported a sparing action upon the methionine needs of the pig when a crude APF supplement (containing an antibiotic) was added to a corn-peanut meal basal ration. Thus it seemed desirable to determine whether an antibiotic would have a sparing action upon the tryptophan needs of growing pigs.

Experimental

This investigation consisted of two experiments. In the first trial, thirty-six weanling Duroc pigs averaging approximately 33 pounds in weight were allotted by random distribution into 6 drylot pens of 6 pigs each and placed on experimental treatment for 6 weeks. The

TABLE 2. RESULTS OF TRYPTOPHAN SUPPLEMENTATION OF MEAT AND BONE SCRAP—1ST TRIAL

(6 pigs in each lot on trials lasting 6 weeks)

Lot	Ration	Supplement	Av. initial wt.	Av. daily gain	Av. daily feed	Feed per lb. gain
			lbs.	lbs.	lbs.	lbs.
1	A		32	0.39	1.7	4.31
2	A	0.02% DL-tryptophan	32	0.46	1.8	3.91
3	A	0.06% DL-tryptophan	33	1.03**	3.6	3.49
4	A	0.12% DL-tryptophan	34	1.09**	3.7	3.37
5	B		33	0.96**	3.1	3.24
6	C		33	0.96**	2.9	3.03

** Difference in daily gain highly significant ($P<0.01$) over lot 1.

animals were kept on concrete floors, bedded with wood shavings and were self fed one of the mixed rations listed in table 1. All rations contained approximately 17 percent of crude protein by analysis. The rations fed and the levels of DL-tryptophan added to the rations are listed in table 2.

In the second trial twenty-four Duroc pigs, approximately 6 weeks of age, were allotted by random distribution into 4 drylot pens and placed on experimental treatment for 8 weeks. These pigs were housed and handled similar to the pigs in the first trial and were self fed ration D (table 1). The meat and bone scrap used was a composite of four separate brands purchased on the open market. The supplementations made to this basal ration are listed in table 3.

Amino acid determinations were made on all rations and the amount of naturally occurring tryptophan in each ration is presented in table 1.

TABLE 3. RESULTS OF TRYPTOPHAN AND AUREOMYCIN SUPPLEMENTATION OF MEAT AND BONE SCRAP—2ND TRIAL

(6 pigs in each lot on trials lasting 8 weeks)

Lot	Ration	Supplement	Av. initial wt.	Av. daily gain	Av. daily feed	Feed per lb. gain
			lbs.	lbs.	lbs.	lbs.
7	D		27	0.29	1.8	6.25
8	D	0.04% DL-tryptophan	26	0.64*	2.6	4.02
9	D	0.06% DL-tryptophan	27	0.93**	3.3	3.55
10	D	aureomycin[1]	26	0.34	1.6	4.68

[1] Crystalline Aureomycin HCl added at rate of 10 mg. per pound of feed.
* Difference in daily gain significant ($P<0.05$) over lot 1.
** Difference in daily gain highly significant ($P<0.01$) over lot 1.

Tryptophan was determined by microbiological analysis after alkaline hydrolysis using the method of Kuiken, Lyman and Hale (1947).

Results and Discussion

The results of the first experiment are summarized in table 2. When 0.02 percent of D-L tryptophan was added to ration A both an increase in rate of gain and an increase in feed efficiency were observed. Increasing the supplementary tryptophan to 0.06 percent gave an additional response in both rate of gain and feed efficiency. However, when tryptophan was added at the 0.12 percent level in lot 4, no significant increase in growth rate or feed efficiency resulted over the 0.06 percent tryptophan addition level. The growth response obtained in lot 5 indicated that the soybean oil meal when substituted for half of the meat and bone scrap protein supplied adequate tryptophan for good growth. This substitution also resulted in a slight increase in feed efficiency over lots 3 and 4. In lot 6 where soybean oil meal constituted the only protein supplement in the mixed feed, growth equaled that obtained in lots 3, 4 and 5 and efficiency was improved.

The divergence in growth between lots occurred shortly after the pigs were placed on experiment and continued for the remainder of the trial. Lots 1 and 2 showed poor growth and at the end of the experiment were uniformly small, but exhibited no other outward signs of a tryptophan deficiency.

Results of the second trial are presented in table 3. The same general response to tryptophan additions can be noted as in the first trial. By adding 0.04 percent of DL-tryptophan to the basal ration D the growth rate was approximately doubled and feed efficiency increased. Addition of 0.06 percent of DL-tryptophan to the basal ration resulted in a tripling of the growth rate over the basal lot 7 and showed a growth rate similar to that obtained in lot 3 (1st experiment). Feed efficiency was also substantially increased. The addition of crystalline aureomycin to the basal ration showed no effect on growth; however, a substantial improvement in feed efficiency was noted.

The results of these two trials indicate that the meat and bone scrap used did not contain sufficient tryptophan to allow for normal growth. The addition of 0.06 percent of DL-tryptophan to the basal rations apparently supplied enough tryptophan to correct the deficiency and thus balance the protein. The addition of aureomycin to the ration already deficient in tryptophan did not apparently correct this deficiency as evidenced by the growth rate. Wilder and coworkers (1951)

working with rats, however, found that the addition of either 0.2 percent DL-tryptophan or 0.25 percent of a B_{12} antibiotic supplement to a corn-meat scrap ration stimulated growth similarly but were not additive in their growth stimulation.

Summary

A corn-meat and bone scrap ration supplemented with minerals and vitamins was found to be inadequate for the growth of pigs fed in drylot. The addition of 0.06 percent of DL-tryptophan to this ration allowed growth to proceed at the same rate as that observed on a corn-soybean oil meal diet. When half of the meat and bone scrap protein was replaced with soybean oil meal protein growth equaled that obtained in the corn-soybean oil meal lot. Aureomycin was not effective in counteracting the tryptophan deficiency of the basal ration.

Bibliography

Almquist, H. J., E. L. R. Stokstad, and E. R. Halbrook. 1935. Supplementary values of animal protein concentrated in chick rations. Jour. Nutr. 10:193.

Beeson, W. M., E. T. Mertz and D. C. Shelton. 1949. Effect of tryptophan deficiency on the pig. JOURNAL OF ANIMAL SCIENCE 8:629.

Cunha, T. J., H. H. Hopper, J. E. Burnside, A. M. Pearson, R. S. Glasscock and A. L. Shealy. 1949. Effect of vitamin B_{12} and APF supplement on methionine needs of the pig. Arch. Biochem. 23:510.

Kuiken, K. A., C. M. Lyman and Fred Hale. 1947. Factors which influence the stability of tryptophan during hydrolysis of proteins in alkaline solution. Jour. Biol. Chem. 171:551.

Kraybill, H. R. 1947. The nutritive value of meat scraps. The National Provisioner 116:123.

Kraybill, H. R., and O. H. M. Wilder. The nutritive value of meat scraps and tankages. A report by the American Meat Institute, Chicago, Ill. 1947.

March, B. E., D. Stupich and J. Biely. 1949. The evaluation of the nutritional value of fish meals and meat meals. Poul. Sci. 28:718.

March, B. E., J. Biely, and R. J. Young. 1950. Supplementation of meat scrap with amino acids. Poul. Sci. 29:444.

Shelton, D. C., W. M. Beeson, and E. T. Mertz. 1951. Quantitative DL-tryptophan requirements of the weanling pigs. JOURNAL OF ANIMAL SCIENCE 10:73.

Wilder, O. M., C. R. Myers, M. M. Darrow and M. H. Hanke. 1951. Nutritive value of meat scrap and tankage. Progress Report American Meat Institute Foundation. Bulletin 10:29.

THE INFLUENCE OF HEAT TREATMENT AND SOLVENT UPON THE NUTRITIVE VALUE OF SOYBEAN OIL MEAL FOR SWINE

D. E. Becker, C. R. Adams, S. W. Terrill, and R. J. Meade[1]

University of Illinois

WITH the rat Osborne and Mendel (1917) initially observed that cooked soybeans supported satisfactory growth when fed as the sole source of protein, although raw soybeans gave poor growth. Likewise, Robison (1930) found with the pig that the nutritive value of soybeans was improved after heating. This was confirmed by Shrewsbury, *et al.* (1932) who postulated the presence of toxic materials in the raw soybean which could be destroyed or removed by heating. In this regard, Ham and Sandstedt (1944) have found that the raw soybean contains a substance which inhibits the activity of trypsin and which depresses the growth of chicks when added to the diet. Simon and Melnick (1950) have studied the nutritive value of soybean products in various stages of heat exposure. They have reported that an inverse correlation exists between the protein value of soya products and their antitryptic potency, although there are cases where the nutritive value can be markedly increased by heating which does not appreciably affect the antitryptic activity. For instance, a bakery-type soya product was strikingly improved in nutritive value over an unheated product, although there was no measurable loss in its *in vitro* antitryptic activity.

Robison (1951) has recently shown that a "moderately" toasted solvent soybean oil meal was slightly inferior to an expeller soybean oil meal; whereas, in another test, a "thoroughly" toasted product was somewhat superior to the expeller-process meal.

The objectives of the studies reported herein were to study the nutritive value of hexane-defatted soybean residues which were exposed to three different heat treatments, and to compare a trichloroethylene-extracted meal with a hexane-extracted product.

[1] We are indebted to A. E. Staley Manufacturing Co., Decatur, Illinois, and to Lederle Laboratories, Pearl River, New York, for funds or products which made this investigation possible. The authors also wish to acknowledge the aid of Sleeter Bull, University of Illinois, with the slaughter studies; H. W. Norton, University of Illinois, with the statistical analysis; and A. W. Turner, A. E. Staley Manufacturing Co., Decatur, Illinois, with laboratory analyses.

Experimental

Experiment I

In the following investigations four different defatted soybean residues were studied for their nutritive value for swine. Table 1 presents a characterization of the products tested. All residues were without hulls, except the trichloroethylene-extracted meal which was sampled from a different lot. The duration of heat exposure for the desolventized meal was equivalent to the heating encountered in removing the solvent (hexane). Further, the duration of heating for the partially and regularly toasted meals represents that heating which occurs in one and two french cookers, respectively, after desolventization.

TABLE 1. A CHARACTERIZATION OF THE SOYBEAN RESIDUES TESTED

Soybean Residue	Heat Exposure	H_2O	Crude Protein	Ether Extract	Water-soluble[1] Protein	Urease[2] Activity
Solvent—Heat Designation		%	%	%	%	ml.
A. Hexane—Desolventized	18–20 min. at 210–220°F	7.2	52.6	0.8	30.6	26.6
B. Hexane—Partially Toasted	33–37 min. at 210–220°F	11.2	51.3	0.5	7.8	0.7
C. Hexane—Regularly Toasted	48–55 min. at 210–240°F	9.8	51.1	0.5	10.8	0.3
D. Trichloroethylene—Regularly Toasted	38–40 min. at 210–230°F	13.6	48.3	0.6	4.0	0.6

[1] Expressed as follows:

$$\text{Water-soluble Protein} = \frac{\text{water-soluble protein}}{\text{total crude protein}} \times 100.$$

[2] Determined by a modified procedure of Bohn and Favor (1945).

Experimental Procedure. Sixty-four pigs of approximately weaning age were allotted into eight groups on the basis of weight, litter, sex, breed, and general condition. The pigs had previously been weaned from sows which had been fed adequate rations on pasture. Hampshire, Duroc, and Chester White breeds were represented. Each lot of pigs was placed in a one-half acre rye pasture which contained adequate housing. The pigs were self-fed *ad libitum* the rations presented in table 2. An adequate supply of water was maintained. The pigs were weighed individually at biweekly intervals and records were kept on feed consumption.

The growth data were treated statistically by analysis of variance as outlined by Snedecor (1946).

In order to ascertain the effect of feeding aureomycin upon the carcass, representative animals were taken from the lots (excluding lots

1 and 2) at a liveweight of 200 pounds for carcass studies. Cold carcass weights were obtained after being held in the cooler at 32° F. for approximately 40 hours. Thickness of backfat was determined by averaging measurements taken at the 1st thoracic, 13th thoracic, and 1st sacral vertebrae.

Results. The growth and feed data for Experiment 1 are presented in table 3.

From weaning to 100 pounds liveweight the analysis of variance indicated a highly significant difference ($P<0.01$) among the soybean

TABLE 2. COMPOSITION OF RATIONS FED[1]
EXPERIMENT I

Lot. No.[2]	1	3	5	7
Soybean Residue	(A) Hexane Desolventized	(B) Hexane Partially Toasted	(C) Hexane Regularly Toasted	(D) Trichloroethylene Regularly Toasted
Ingredients:	%	%	%	%
Ground yellow corn	74.5	73.9	73.9	71.5
Soybean residue	18.5	19.1	19.1	21.5
Alfalfa meal, dehydr.	5.0	5.0	5.0	5.0
Steamed bone meal	0.8	0.8	0.8	0.8
Ground limestone	0.8	0.8	0.8	0.8
Common salt	0.4	0.4	0.4	0.4
Total	100.0	100.0	100.0	100.0

[1] Calculated 17% crude protein. After an average liveweight of approximately 75 pounds the ratio of corn and soybean residue was so altered to yield rations containing 14% crude protein.
[2] Rations for lots 2, 4, 6 and 8 were the same as lots 1, 3, 5 and 7, respectively, with the addition of aureomycin hydrochloride at 5 mg. per pound.

residues. The data showed that only the desolventized soybean meal failed to support normal weight gains; whereas, the remaining products performed equally well. Statistical comparisons of the residues showed that the desolventized meal was different ($P<0.01$) and there was no significant variation among the remaining meals. In general, the efficiency of feed utilization varied directly with the rate of gain.

It was interesting to note the grazing habits during the test. Pigs receiving the desolventized meal kept the forage grazed considerably closer, although there was little, if any, difference in the remaining lots. Observations did not indicate that the feeding of an antibiotic exerted any effect upon this characteristic.

Aureomycin failed to yield a growth response in lot 2, and likewise,

TABLE 3. RESULTS OF THE GROUP-FEEDING TEST
EXPERIMENT I

Lot. No.	1	2	3	4	5	6	7	8
Treatment Soybean Residue	(A) Hexane Desolventized		(B) Hexane Partially Toasted		(C) Hexane Regularly Toasted		(D) Trichloroethylene Regularly Toasted	
Aureomycin HCl	0	+	0	+	0	+	0	+
Weaning to 100 lbs.								
No. of pigs	8	8	8	8	8	8	8	8
Av. initial wt., lb.	37.8	37.5	37.6	37.9	37.5	37.6	37.6	37.6
Av. final wt., lb.	104.9	102.8	95.0	102.4	94.8	106.8	90.2	102.4
Av. daily gain, lb.	0.84	0.82	1.01	1.13	1.00	1.21	0.92	1.14
Av. daily feed per pig, lb.	3.69	3.18	3.36	3.81	3.28	3.80	3.26	3.39
Av. feed per lb. gain, lb.	4.40	3.90	3.34	3.37	3.26	3.13	3.53	2.98
Weaning to 200 lbs.								
No. of pigs	8	8	8	8	6[1]	8	8	8
Av. final wt., lb.	185.2	180.0	195.1	199.8	200.6	199.5	190.4	191.8
Av. daily gain, lb.	1.06	1.01	1.18	1.24	1.34	1.27	1.13	1.18
Av. daily feed per pig, lb.	4.68	4.28	5.17	5.41	5.27	4.98	4.76	4.74
Av. feed per lb. gain, lb.	4.45	4.26	4.40	4.41	4.17	3.96	4.27	4.09

[1] Two pigs which showed evidence of erysipelas were not included in the final phase.

it is noteworthy that the feed consumption was not increased over the control, although the feed efficiency was improved. However, in the remaining lots aureomycin did yield an increment in feed consumption and daily bodyweight gains; there was a similar improvement in efficiency of feed utilization, except in the case of the group receiving the partially toasted residue. The magnitude of this growth response to the antibiotic varied directly with the length of the heat treatment applied to the soybean residue fed. The analysis of variance indicated a significant ($P<0.05$) aureomycin effect from weaning to 100 pounds.

For the entire experimental period from weaning to 200 pounds liveweight the various soybean residues responded somewhat differently than in the early growth period. Likewise, the extent of the growth

TABLE 4. ANALYSIS OF VARIANCE OF AVERAGE DAILY GAINS EXPERIMENT I—WEANING TO 100 POUNDS LIVEWEIGHT

Source of Variance	d/f	Variance
Treatments	7	.1674**
Between soybean residues	3	.2498**
Aureomycin vs. none	1	.2770**
Interaction	3	.0486
Breeds	2	.4852**
Error Term	54	.0498

** $P<0.01$.

response to aureomycin diminished so that the over-all effect failed to be of statistical significance.

Two Chester White pigs were removed from Lot 6 after they had been on test for 57 days. Since this resulted in a disproportionality of subclass numbers for the study from weaning to 200 pounds the data were treated by the method of fitting constants. Such analysis revealed an insignificant aureomycin effect, and the differences between soybean residues and between breeds were highly significant ($P<0.01$). Individual statistical comparisons showed that the regularly and the partially toasted hexane-extracted residues were both superior to the desolventized product ($P<0.01$), and the former product also excelled the trichloroethylene-extracted meal ($P<0.05$). All other comparisons were not significant.

The slaughter data collected which are presented in table 5 showed that pigs which yielded a growth response to aureomycin from weaning to 100 pounds possessed a statistically significant ($P<0.05$) thicker

TABLE 5. SLAUGHTER DATA FOR EXPERIMENT 1

Group No.	1	2
Treatment	Control (Lots 3, 5 & 7)	Aureomycin HCl (Lots 4, 6 & 8)
No. of pigs slaughtered	12	11
Av. liveweight, lb.	202.8	204.3
Av. cold carcass weight, lb.	156.3	160.7
Av. dressing percentage, lb.	77.1	79.0
Av. backfat thickness, cm.*	3.7	4.1

* Significantly different ($P<0.05$) according to Students "t" test.

backfat. There was a trend in dressing percentage which favored the antibiotic-fed pigs, but it was not of statistical significance.

Experiment II

Experimental Procedure. In this study the relative quality of protein in the four soybean residues was determined by the growth method

TABLE 6. COMPOSITION OF RATIONS FED EXPERIMENT II

Lot No.	1	2	3	4
Soybean Residue	(A) Hexane Desolventized	(B) Hexane Partially Toasted	(C) Hexane Fully Toasted	(D) Trichloroethylene Fully Toasted
Ingredients:				
Soybean Residue	19.0	19.5	19.5	20.5
Corn starch	51.8	51.4	51.4	51.3
Cerelose	23.7	23.6	23.6	23.5
Crude corn oil	1.4	1.4	1.4	1.3
Wood flock	1.6	1.6	1.6	0.9
Mineral Mixture[1]	2.0	2.0	2.0	2.0
A and D oil (4000A-750D)	0.5	0.5	0.5	0.5
Vitamin Mixture[2]	+	+	+	+
Aureomycin HCl[3]	+	+	+	+
Total	100.0	100.0	100.0	100.0
Crude Protein, percent[4]	9.79	9.82	10.2	9.96

[1] Dyer and Krider (1950).
[2] Vitamins added per pound of ration: 0.5 mg. thiamine HCl, 1.4 mg. riboflavin, 6.0 mg. niacin, 3.7 mg. calcium pantothenate, 0.6 mg. pyridoxine, 454 mg. choline chloride, and 9.0 mcg. vitamin B_{12}.
[3] 5 mg. per pound.
[4] By analysis according to A.O.A.C.

proposed by Osborne, *et al.* (1919) as modified for use with the pig by Geurin, *et al.* (1951).

Sixteen weanling Chester White and Duroc pigs were divided into four blocks on the basis of litter, weight, general condition, and thriftiness. Individuals within each block were then assigned at random to the four treatment groups. The rations which were equated with regard to protein, fat, and fiber at approximately 10.0, 2.0, 2.0 percent, respectively, are presented in table 6. The pigs were individually hand-fed

TABLE 7. RESULTS OF PROTEIN EFFICIENCY TEST
EXPERIMENT II

Lot No.	1	2	3	4
Soybean Residue	(A) Hexane Desolventized	(B) Hexane Partially Toasted	(C) Hexane Regularly Toasted	(D) Trichloroethylene Regularly Toasted
Items Compared:				
Number of pigs	4	4	4	4
Number of days	37	37	37	37
Av. initial wt., lb.	38.2	37.8	37.8	38.0
Av. final wt., lb.	55.8	75.8	81.8	64.5
Av. daily gain lb.[1]	0.47	1.03	1.19	0.72
Av. daily feed intake per pig, lb.	2.09	2.74	2.87	2.36
Av. feed per lb. gain, lb.	4.42	2.67	2.41	3.29
Gain per lb. protein consumed, lb.[2]	2.20	3.81	4.23	3.05

Least significant differences at P=0.05 and P=0.01 are as follows:
[1] 0.15 and 0.21 lb.
[2] 0.70 and 1.02 lb.

twice daily in individual feeding stalls at as nearly full feed as possible. Water was available at all times. Daily feed records and weekly liveweights were recorded. The data were treated statistically by analysis of variance according to Snedecor (1946).

Results. The results of the protein efficiency test (Experiment II) are presented in table 7. On the basis of average daily gain the regularly toasted hexane-extracted meal was superior to all other products. However, from the standpoint of gain per pound of protein consumed the regularly heated product failed to be statistically superior to the partially toasted meal. The desolventized meal produced unsatisfactory results and the trichloroethylene-processed meal was only mediocre in value although it had been exposed to a regular toast. Testing the

data with analysis of covariance in order to adjust the daily gains for variations in feed intake, also indicated a significant difference ($P<0.05$) between the soybean residues.

Discussion

Although the two trials did show agreement, it should be emphasized that they did not yield similar data to indicate the relative value of the soybean residues as sources of protein. In Experiment I the products were tested as supplementary sources of protein to a grain ration for pigs on pasture; whereas, in Experiment II the objective was to ascertain the quality of protein in the products when they contributed the sole supply of protein for the pig. Certainly the latter technic is a more critical test of protein quality.

Some heating beyond the heat exposure of desolventization is essential for maximum nutritive value of defatted soybean residues for the pig. Furthermore, there appears to be some advantage for heating in a second french cooker, although a major share of the improvement in nutritive value is accomplished by the initial cooking. The results presented here agree with those of Simon and Melnick (1950) who reported poor correlation between antitryptic activity as a measure of proper heat exposure and the nutritive value of soya products. Using water soluble protein and urease activity as indices of adequate heating we found no relationship with nutritive value in the case of the partially and regularly toasted hexane-extracted residues.

Contrary to the observations of Pritchard, *et al.* (1952) with the ruminant species, the trichloroethylene-extracted meal seemed quite innocuous when used as a source of protein for the pig. Although the quality of protein in the trichloroethylene-extracted meal is apparently lower than for a properly heated hexane-processed meal, the pigs did not show any untoward symptoms from its use in either test.

In view of the puzzling nature of the growth response exhibited by swine to an antibiotic in the ration, it was quite interesting to observe that apparently the desolventized meal possessed some factor which entirely suppressed a gain increment to dietary aureomycin. It is further indicated that this factor is destroyed or rendered inactive by exposure to heat. Since the pigs receiving the desolventized meal exhibited a depressed feed consumption, this action may have prevented an aureomycin growth response. In this regard, Brown, *et al.* (1951) have shown that the growth response to aureomycin seems to be mediated through an increased feed consumption in the pig.

Furthermore, the data presented here confirm the earlier observations of Terrill, *et al.* (1951) who found that the growth response to an antibiotic was more marked with weanling pigs than with pigs weighing 100 pounds and also that antibiotic-fed pigs exhibited a somewhat thicker backfat at slaughter. Catron, *et al.* (1952) has recently reported that antibiotic feeding failed to influence backfat depth, length or depth of body, and percent of lean in the swine carcass.

Summary

The influence of heat treatment and solvent used in the processing of soybeans upon the nutritive value of the meal produced was tested with the growing-fattening pig.

Soybean residues which had been, (A) hexane extracted-desolventized, (B) hexane extracted-partially toasted, (C) hexane extracted-regularly toasted, and (D) trichloroethylene extracted-regularly toasted were studied. Each meal was fed as a supplementary source of crude protein with yellow corn, alfalfa meal, and minerals to pigs on winter rye pasture from weaning to 200 pounds. All rations were fed with and without aureomycin HCl at 5 mg. per pound. During early growth results showed that B, C, and D did not differ significantly but they were superior to A; whereas, for the entire study differences widened so that B was also superior to D which, in turn, failed to statistically excel A. Apparently D possessed no toxic properties. Aureomycin stimulated a significant increase in gains from weaning to 100 pounds; whereas, its effect to final weight was not statistically significant. The magnitude of the response to aureomycin varied directly with the length of heat treatment applied to the soybean residue; supplementary aureomycin with ration containing A failed to produce a growth response. Pigs yielding a growth response to the antibiotic exhibited a thicker backfat than controls.

In a protein efficiency test, semi-purified rations containing 10 percent crude protein solely from the test soybean oil meals were fed to weanling pigs in drylot for 37 days. The results indicated all of the meals tested were significantly different in protein quality.

Literature Cited

Bohn, R. T. and H. H. Favor. 1945. Functional properties of soya flour as a bread ingredient. Cereal Chem. 22:296.

Brown, P. B., D. E. Becker, S. W. Terrill, and L. E. Card. 1951. The effect of aureomycin on the rate of gain and efficiency of feed utilization by growing-fattening swine. JOURNAL OF ANIMAL SCIENCE 10:1042.

Catron, D. V., A. H. Jensen, P. G. Homeyer, H. M. Maddock, and G. C. Ashton. 1952. Re-evaluation of protein requirements of growing-fattening swine as influenced by feeding an antibiotic. JOURNAL OF ANIMAL SCIENCE 11:221.

Dyer, I. A. and J. L. Krider. 1950. Choline versus betaine and expeller versus solvent soybean meal for weanling pigs. JOURNAL OF ANIMAL SCIENCE 9:176.

Geurin, H. B., J. A. Hoefer, and W. M. Beeson. 1951. Protein efficiency of corn by-products and other protein feeds for swine growth. JOURNAL OF ANIMAL SCIENCE 10:607.

Ham, W. E. and R. M. Sandstedt. 1944. A proteolytic inhibiting substance in the extract from unheated soybean meal. Jour. Biol. Chem. 154:505.

Osborne, T. B., L. B. Mendel and E. L. Ferry. 1919. A method of expressing numerically the growth-promoting value of proteins. Jour. Biol. Chem. 37 (2):223.

Osborne, T. B. and L. B. Mendel. 1917. The use of soybean as food. Jour. Biol. Chem. 32:369.

Pritchard, W. R., C. E. Rehfeld, and J. H. Sautter. 1952. Aplastic anemia of cattle associated with ingestion of trichloroethylene-extracted soybean oil meal (Stockman Disease, Duren Disease, Brabant Disease) 1. Clinical and laboratory investigation of field cases. Jour. Amer. Vet. Med. Assoc. 121:1.

Robison, W. L. 1930. Soybeans and soybean oil meal for pigs. Ohio Agr. Exp. Sta. Bul. No. 452.

Robison, W. L. 1951. Soybean oil meal for pigs. Ohio Agr. Exp. Sta. Res. Bul. 699.

Shrewsbury, C. L., C. M. Vestal, and S. M. Hauge. 1932. The effect of yeast and casein supplements to corn and soybean rations when fed to rats and swine. Jour. Agr. Res. 44:267.

Simon, Morris, and Daniel Melnick. 1950. The *in vitro* digestibility of raw and heat-processed soy products varying in the nutritive value of protein. Cereal Chem. 27:114.

Snedecor, G. W. 1946. Statistical Methods. 4th Ed. Iowa State College Press, Ames, Iowa.

Terrill, S. W., D. E. Becker, C. R. Adams, and R. J. Meade. 1952. Response of growing-fattening pigs to bacitracin, aureomycin, and other supplements. JOURNAL OF ANIMAL SCIENCE 11:84.

TRANSMITTANCE OF FOREIGN ORGANIC COMPOUNDS FROM THE FEED TO THE FLESH OF SWINE

PAAVO ROINE, MATTI ANTILA, and INKERI SUHONEN[1]
University of Helsinki[2]

PIG feeding operations are frequently located in connection with slaughterhouses, fish-refineries, dairies, etc. to make use of waste material. Decomposition of proteins, fats and carbohydrates in this waste material may have taken place and as a feed they can thus contain appreciable amounts of substances which usually are considered toxic. Because of the effective detoxication mechanism of the pig, however, these substances usually are not supposed to cause any harm to the animals or make the flesh unfit for use as human food.

It is well known that in some cases the swine flesh takes on abnormal tastes and odors, arising from the feed used. Fish meal gives to the flesh a fishy taste, filthy flour its own peculiar taste, etc. In these cases it is evident that foreign compounds have been transmitted from the feed to the flesh, particularly to the fatty tissues. The idea prevails that when pigs are fed spoiled animal residues, toxic decomposition products may pass into the flesh. In extreme cases the flesh might even become unsafe for human consumption. In this connection we can point to the phenomenon of autointoxication, poisoning which has been assumed to be caused by toxic metabolic products elaborated in the intestines from the food material.

In a more general sense, also, the question of the ability of foreign organic compounds to pass over from the foodstuffs to the tissues and organs has become interesting. Increasing numbers of new insecticides, fungicides, etc. are now used to treat growing crops and stored food products. Small quantities of these additives might well find their way into the human organism. In addition, as Virtanen (1935, 1951) has shown, plants may absorb through the roots, organic compounds from the soil and thus contain substances which are repulsive or even toxic to the animals. Although experimental proof of the toxicity of foodstuffs containing these foreign substances is not an easy task, the question obviously deserves serious consideration.

In the present investigation an attempt was made to determine whether feeding spoiled animal waste material results in an accumulation

[1] We are indebted to Dr. V. Rislakki for the veterinary inspection of the animals.
[2] Department of Nutritional Chemistry, Helsinki, Finland.

TABLE 1. FEEDING OF THE PIGS

(The average daily rations per group. Group A: 4 pigs, B and C: 3 pigs)

Group	June	July	August	September
A	10 kg. meat scraps 4 " barley	20 kg. meat scraps 3 " barley horse manure	30 kg. meat scraps 3 " barley horse manure	40 kg. meat scraps horse manure
B	3 kg. red clover 12 l. skim milk 3 kg. barley	5 kg. red clover 15 l. skim milk 6 kg. barley	10 kg. green fodder 15 l. skim milk 6 kg. barley	20 kg. green fodder 15 l. skim milk 3 kg. barley
C	3 l. skim milk 25 " whey 3 kg. barley	40 l. whey 5 kg. barley	50 l. whey 5 kg. barley small amount of green fodder	50 l. whey 5 kg. barley 2 " wheat bran

of foreign substances in swine flesh. An experiment was also carried out to determine whether such flesh when fed in large amounts was harmful to rats.

Experimental

Feeding of Pigs

Ten pigs weighing from 24 to 32 kg. were divided into three groups; group A consisted of 4 animals, groups B and C of 3 animals each. The average composition of the rations used for the different groups is given in table 1. Feeding meat scraps and horse manure were typical for group A, that of green fodder and skim milk for group B, and whey for group C. The raw meat scraps obtained from a slaughterhouse were allowed to become spoiled at room temperature (20–25° C.) for 2–3 days after which they were fed to the animals in a bad-smelling state.

TABLE 2. THE AVERAGE GROWTH OF PIGS

Group	Weight, kg. Beginning	Gain of weight kg.
A	28.6	67.7
B	27.6	58.9
C	28.3	65.2

The animals in this group had a constant diarrhea, but no other ill effects due to the ration were noticed. The experimental period began on June 10 and lasted until September 20. The growth data of the pigs are shown in table 2. At the termination of the experiment the animals were slaughtered and the carcasses were inspected by a veterinarian. No characteristic differences between the groups were found. Samples of lard were taken from the top of the shoulder and samples of lean meat also from the shoulder. These as well as the livers were frozen and stored at —20° C.

Examination of the Flesh

In taste and odor tests samples of lard, meat and liver were either roasted or ground with water and slightly heated. All the group A samples, and the lard in particular, revealed repulsive tastes and odors sharply differing from the samples of the other groups. It was evident that bad-smelling and bad-tasting compounds had passed over from the feed to the flesh.

The quality of the *lard* samples was examined by various chemical

and physical tests. Characteristic fat constants (Juckenack *et al.*, 1939) are given in table 3. It can be seen that in most cases practically no differences exist between the different groups. The moisture content is somewhat higher in the "whey group" (C). The "meat scrap group" (A), on the other hand, differs from the others by a lower melting point and higher iodine and thiocyanate values.

In order to find whether the lard from group A contained substances originating from the spoiled meat scraps used in the feeding, preliminary chemical examinations were carried out. These included qualitative tests for methylketones (Juckenack *et al.*, 1939), primary and secondary amines and phenol (Millon test) (Rosenthaler, 1923), indole and

TABLE 3. CHEMICAL CHARACTERISTICS OF THE LARD SAMPLES

Item	Average values of samples in Group A	Group B	Group C
Moisture and volatile matter, %	6.5	7.5	9.4
Fat content, % of dry matter	98.0	97.6	98.3
Specific gravity at 30° C	0.898	0.896	0.900
Melting point, ° C	43.5	45.3	44.9
Solidifying point, ° C	26.9	27.1	27.3
Saponification value	197.1	197.5	197.6
Iodine value	49.7	48.5	47.3
Thiocyanate value	47.5	46.5	46.6
Reichert-Meissl value	0.39	0.39	0.38
Polenske value	0.33	0.28	0.40
Acetyl value	5.3	4.9	5.1

skatole (Ehrlich test) (Rosenthaler, 1923; Sasaki, 1910; and Fellers and Clough, 1925). Quantitative estimations of volatile aldehydes (Juckenack *et al.*, 1939), phenol (Sanders and Sager, 1946), and trimethylamine (Hartman, 1944) were also made. In general, the amounts of the substances tested for were very small and, therefore, exact figures for these preliminary estimations cannot be given. However, it was found that the lard from group A contained volatile aldehydes, methylketones, secondary amines, trimethylamine, and skatole in distinctly greater quantity than the lard from the control groups B and C. Similar, although not as clear-cut differences, were found in the amounts of primary amines and phenol. The results obtained thus confirm the findings made on taste and odor tests that some degradation products of the feed in the meat scrap group had passed over to the flesh of the animals. A closer characterization of these substances evidently demands more sensitive methods than those used in these

preliminary tests. The next step in the investigation, therefore, will be the use of chromatographic methods.

Feeding Test with Rats

The possible toxic effect on rats of the meat scrap group flesh was tried in growth experiments. The rats were fed either (Series I) a diet consisting almost exclusively of the flesh of the experimental pigs or (Series II) a diet in which a part of the flesh was replaced with sucrose. The composition of the diets was as follows:

Series I:	Swine meat of groups A, B, or C	78 percent
	Swine liver " " " " " "	18 "
	Salts 4 (Hegsted *et al.*, 1941)	4 "
Series II:	Swine meat of groups A, B, or C	52 "
	Swine liver " " " " " "	12 "
	Sucrose	32 "
	Salts 4	4 "

In addition, one group of rats fed the ordinary stock diet of the laboratory was included in the experiment. This stock diet consisted of oat meal 40 percent, rye-meal 28 percent, casein 15 percent, margarine 4.8 percent, salt mixture (containing 1000 grams sodium chloride, 100 grams calcium lactate, 80 grams ferric citrate, 10 grams manganese sulfate, 2 grams copper sulfate and 0.2 grams potassium iodide) 2 percent, dried brewer's yeast 10 percent, and cod liver oil 0.2 percent. Once a week each rat was given 5 grams of fresh beef liver and several drops of Evitol (vitamin E concentrate).

The animals used were yellow-hood rats of a local strain from the Department of Animal Husbandry. They were kept in individual cages and fed *ad libitum*. The growth data are given in table 4.

TABLE 4. GROWTH RESPONSE OF RATS FED DIETS CONTAINING SWINE-FLESH FROM GROUPS A, B, OR C

Diet		No. and sex of rats	Average initial weight g.	Average gain in 9 weeks g.
Series I	A	2 ♂ + 3 ♀	36	166
	B	do	37	141
	C	do	36	167
Series II	A	2 ♂ + 2 ♀	37	176
	B	do	33	192
	C	do	33	182
Stock		3 ♂ + 5 ♀	44	148

The results of Series I and II are not strictly comparable with each other or with those of the stock group since the sex distributions were not identical. It can be seen, however, that growth in all flesh groups was very good as compared with the stock group. It is also evident that there are no significant differences between the groups A, B, and C within the Series I or II. No differences were found even when the experiment was continued for 19 weeks with a part of the animals. The autopsy of the animals revealed no systematic differences between the group A, on the one hand, and the groups B and C.

The rat experiment indicated that the flesh of the meat scrap-group had no toxic effects on the rats even when fed at very large levels. This is well understandable in the light of a separate experiment in which rats were fed large amounts of intentionally putrefied meat without noticing any evident intoxication. The detoxicating mechanism of the rats seemed to render harmless rather large amounts of putrefaction products found in the food.

Summary

An attempt was made to determine whether deterioration products of organic material occasionally found in feeds are transferred to swine flesh and whether such flesh has harmful effects when fed to rats. Four young pigs were fed for a period of three months a ration containing large amounts of spoiled meat scraps and some horse manure. Two control groups of three pigs each were fed either barley, green fodder and skim milk, or rations containing barley and whey. Taste and odor tests showed that the flesh of the meat-scrap group had taken on repulsive tasting and smelling substances. In preliminary chemical analyses it was found that, as compared with the control groups, the lard of the meat scrap group contained distinctly more volatile aldehydes, methylketones, secondary amines, trimethylamine and skatole and also more primary amines and phenol. In growth experiments with rats, however, no differences were found between the animals fed large amounts of the flesh of the several pig groups.

Literature Cited

Fellers, C. R. and R. Clough. 1925. Indol and skatole determination in bacterial cultures. Jour. Bact. 10:105.

Hartman, S. 1944. Experimentelle studier over de oxidative virkninger i smør og maelk. Beret. fra stat. forsøgsmejeri, Hillerød 41:73.

Hegsted, D. M., R. C. Mills, C. A. Elvehjem and E. B. Hart. 1941. Choline in the nutrition of chick. Jour. Biol. Chem. 138:459.

Juckenack, A., E. Bames, B. Bleyer and J. Grossfeld. 1939. Handbuch der Lebensmittelchemie, IV Fette und Öle. Verlag Julius Springer, Berlin.

Rosenthaler, L. 1923. Nachweis organischer Verbindungen. Ferdinand Enke Verlag, Stuttgart.

Sanders, G. P. and O. S. Sager. 1946. Modification of the phosphatase test as applied to cheddar cheese and application of the test to fluid milk. Jour. Dairy Sci. 24:737.

Sasaki, T. 1910. Über eine neue empfindliche skatolreaktion. Biochem. Z. 23:402.

Virtanen, A. I. 1935. Om växternas förmåga att upptaga jordens organiska beståndsdelar. Nord. Jordbruksforskning 17:203.

Virtanen, A. I. and R. Schwyzer. 1951. Uptake of lower aliphatic amines by pea plants. Acta Chem. Scand. 5:1397.

EXPERIMENTAL TEST OF PREDICTIONS OF INBRED LINE PERFORMANCE IN CROSSES[1, 2]

JAMES V. CRAIG[3] and A. B. CHAPMAN[4]

University of Wisconsin

MUCH research in livestock breeding in recent years has been directed toward the development of inbred lines and in the testing of such lines for their usefulness in increasing levels of productivity by linecrossing and topcrossing. Simple, rapid and reliable methods for detecting lines of potentially high combining value are needed by breeders following plans of this kind.

The primary aim of the pilot experiment reported here was to determine the relative value of different methods for predicting the outcome of specific crosses and for predicting the average (or general) combining value of lines for the quantitative character, 13-week individual body weight in the rat. This early adult body weight was estimated to be 40–50 percent heritable from data collected on outbred rats in this study.

This experiment also provides information on the effects of inbreeding, linecrossing, topcrossing (inbred sires on unrelated outbred dams) and bottomcrossing (outbred sires on unrelated inbred dams) for this quantitative character. Data from the mating systems indicated above were studied to determine whether hybrid vigor was of importance and whether the mode of gene action could be established.

Material and Methods

Eight inbred lines were available for study. Five lines were derived from a commercial strain brought into this laboratory October 1949. These five lines were designated G2, G5, G6, G22 and G25. The sires and dams used in crossing had inbreeding coefficients of .25 and .375, resulting from brother-sister, sire-daughter or both kinds of matings. Two lines, designated Mi4 and Mi7, were developed in the ovarian

[1] Paper from the Department of Genetics, No. 503. Published with the approval of the Director of the Agricultural Experiment Station.

[2] Supported in part by the Research Committee of the Graduate School from funds supplied by the Wisconsin Alumni Research Foundation.

[3] Present address: Department of Animal Science, College of Agriculture, University of Illinois, Urbana, Illinois.

[4] The authors wish to express their appreciation to Drs. W. F. Dunning and M. R. Curtis, Detroit Inst. Cancer Research, for providing the highly inbred rats obtained from Wayne University in 1943. They also wish to acknowledge the guidance of Dr. H. W. Norton, Station Statistician, University of Illinois, in some of the statistical procedures and the technical assistance of Mrs. James Payton.

response study of Kyle and Chapman (1953) and had inbreeding coefficients of approximately .80. The other line (W) was obtained from Wayne University in 1943 and had been intensely inbred for about 50 generations at the time of this study.

Outbred animals derived from the same source material as the G lines were also maintained in the laboratory by a random mating scheme to serve as a control group for the inbreds of the G lines and for use in topcrossing and bottomcrossing.

Little or no conscious selection for 13-week individual body weight was practiced during the development of the five G lines. Some selection was applied to lines Mi4 and Mi7 by keeping only the heaviest male in each litter at six weeks of age for possible use as a line sire. Final selection of both males and females within these two lines however was based on ovarian response to a gonadotrophic hormone of their full sisters. Such selection for body weight as did occur for males within litters of the Mi lines was weakened by reduction of litter size to six on the day after birth and by retention of a sex ratio as close as possible to one male and five females. Line W was highly inbred when received so that selection for body weight was not likely to be effective in this line. The whole group of lines may be thought of as derived by rapid inbreeding without much conscious selection for body weight.

The effect of variables other than mating system were studied in order that the data could be standardized for some of the environmental and developmental factors affecting this character before making comparisons of mating systems.

Differences between sire progenies within lines and mating systems were also considered to determine whether the level of inbreeding in some lines had left heterogeneity between sires within lines as far as their progeny performance in the different mating systems was concerned.

Inbred performance of lines was estimated from inbred progeny weights of all the sires or of all the dams which were actually used in crossing experiments. These inbred performance estimates were made separately for the progenies of sires and of dams within particular lines and were used in comparisons with progenies of crosses classified on the basis of the sire-line or dam-line involved. The two estimates of each line's own performance were not entirely independent as some inbred offspring of sires which were used in crossing were also the inbred offspring of dams used in crossing.

Inbreeding results were studied to determine to what extent differentiation in body weight had occurred between the G lines and also

between the Mi4 and Mi7 lines. Likewise, it was determined whether any general decline in vigor, as indicated by body weight, had occurred with inbreeding of the G lines.

Crossing inbred lines with outbred stock and with other inbred lines provided evidence on whether differences between inbred lines were maintained in the respective cross-progenies. All possible crosses were made within the limits of availability of breeding animals.

Regressions of specific linecross progeny weights on the average weight of the two inbred parent lines (mid-parent), on the heavier inbred parent line and on the lighter inbred parent line entering each cross were calculated. Regressions of topcross and bottomcross progenies on these three bases also were determined.

Since the same lines (or outbred group) were involved in several estimates of specific cross-progeny results, the degrees of freedom within each regression, as pointed out by Lush (1947), for testing significance lay somewhere between the total number of lines involved (minus two) and the geometric mean of the number of lines and the number of specific crosses (minus two). The minimum and maximum degrees of freedom were therefore used and the estimate of probability was taken as a value lying somewhere between these respective estimates. The magnitude of the correlations of the values entering into each regression were taken as measures of the relative success obtained from using these bases for prediction.

In drawing inferences concerning the mode of gene action and the occurrence of hybrid vigor in cross-progenies, consideration was given to the deviations of mean 13-week individual body weights of the specific crosses from: (a) the mid-parent or average body weight of the component parent lines (or parent line and outbred group) and (b) the heavier parent line (or outbred group) involved in each cross. The latter test was carried out only in those cases where the parent lines (or parent line and outbred group) differed significantly in body weights. This precaution was taken in order that the cross-progenies would not be as likely to be compared with parent lines that were heavier because of chance environmental fluctuations in which cases it would be more proper to make a comparison with a mid-parent value.

The line's own performance, its topcross and bottomcross performance and its performance in each of two test-crosses (one to the light inbred tester line, Mi4, the other to the heavy inbred tester line, Mi7) were used in predicting the probable average combining ability of lines in a series of linecrosses. Line's own performance was used in estimating

the probable average combining ability of different lines for crossing with the outbred strain from which the G lines were formed.

Since unequal subclass numbers were present in the analyses of variance and because estimates and observations were established with varying degrees of precision, weightings were assigned to differences between progenies derived from the different line-mating-system groups and to the cross-products of deviations in regressions and correlations as described by Snedecor (1946, p. 285, *et seq.*)

Results

Effects of Environmental and Developmental Factors

Size of litter at weaning and litter sequence were found to have no clear-cut effect upon adult body weight in these data in which the litter size was restricted to a maximum of six animals on the day after birth. Sex-linkage and maternal influence were found to have no significant effect upon the character. A highly inbred line (W) and the outbred group of animals were classified by bimonthly periods to determine whether unrecognized environmental changes had caused any noticeable trend in adult body weights. No such effect was demonstrable.

A clear-cut sex difference occurs in 13-week individual body weight in the rat. An attempt was made to determine whether the differences between male and female weights were consistent from line to line and from one mating system to another. No interactions between sex and line of male within the topcross and within the linecross progenies were found. A significant ($P<.05$) interaction was, however, found between sex and line of male within the inbred progenies. Demonstrable interaction was lost when a single line's progeny was removed from the data. It was therefore assumed that, for all practical purposes, the females were of the same relative weight with reference to the male weight within the lines and mating systems.

A highly significant interaction was found between sex and mating systems (inbred, topcross and linecross). However, since the extremes in female weight, expressed as percent of male weight for each mating system, deviated only 1 percent from the over-all mean percent, it was decided that a single adjustment factor of .72 would be used to adjust male weights to a female basis.

Effect of Mating System

(a) *Differences Between Sire Progenies Within Lines.* Analyses of variance for sire progeny body weights within lines and within mating

systems were calculated. The numbers of offspring available for individual dams did not warrant a comparable analysis for them. The total number of sires for the eight lines was 28 with a range of one to seven sires per line. Variations between sire progenies within mating systems were significant in two of 23 sire-mating-system analyses. The occurrence of only two significant differences in 23 analyses fails to give convincing evidence of real sire progeny differences. It was therefore concluded that individual sire differences within lines were not important sources of variation and that progenies could be classified by parent line rather than by individual sires within each line. Sires within lines were related

TABLE 1. INBRED PROGENY PERFORMANCE CLASSIFIED BY LINE OF SIRE AND BY LINE OF DAM

Line of Sire			Line of Dam		
Line[1]	No.	Weight	Line[1]	No.	Weight
G22	15	198.7	G22	15	198.7
G2	7	190.0	Mi7	103	195.7
Mi7	59	187.8	G2	11	182.4
G25	61	181.6	Outbred	227	181.8
Outbred	112	179.9	G25	61	181.6
G5	109	172.2	G5	139	175.2
Mi4	129	160.9	Mi4	168	157.7
G6	10	155.4	W	119	142.0
W	153	140.9			
Total	655	174.2[2]	Total	616	176.9[2]

[1] Lines arranged in descending order of body weight.
[2] Unweighted mean of line weights.

at least 60 percent in all cases. Since there was little reason to assume that dam progenies would vary more than sire progenies the same combining of data was done for the dams.

(b) *Inbreeding.* Two main points of interest concerning the G lines are: (a) that significant differences in body weights occurred between progenies of these lines which had been derived from the same source and (b) that little, if any, loss of vigor (body weight) occurred on the average, for this whole group of lines compared to the average of the outbreds derived from the same foundation stock. The two Mi lines formed previous to the initiation of this study differed significantly from each other in body weight. Inbred progeny performance for all lines and for the outbred group is shown in table 1.

(c) *Linecrossing.* Linecrosses were made in all combinations possible within the limitations of the numbers of breeding animals available

TABLE 2. NUMBERS OF OFFSPRING WITHIN LINECROSSES, TOPCROSSES AND BOTTOMCROSSES OF SPECIFIC PARENT INBRED LINES OR OUTBRED GROUP

Breeding of Sire	Breeding of dam									
	W	Mi4	Mi7	G2	G5	G6	G22	G25	Total	Outbred
				(Linecrosses)						(Topcrosses)
W	—	51	55	3	29	0	2	6	146	29
Mi4	53	—	42	8	29	0	16	9	157	37
Mi7	66	60	—	6	36	0	13	9	190	56
G2	41	58	40	—	27	0	4	0	170	45
G5	68	84	50	13	—	0	6	12	233	77
G6	17	15	14	5	6	—	0	0	57	8
G22	16	10	9	0	6	0	—	5	46	6
G25	37	24	12	4	11	0	0	—	88	29
Total	298	302	222	39	144	0	41	41	1087[1]	287[2]
				(Bottomcrosses)						
Outbred	41	48	29	11	31	0	0	10	170[3]	

[1] Total linecross offspring.
[2] Total topcross offspring.
[3] Total bottomcross offspring.

(table 2). Forty-four of 56 possible combinations were made, including reciprocals. The series of crosses classified by sire-line or by dam-line were balanced in so far as possible.

Significant differences were found between average linecross progeny

TABLE 3. DEVIATIONS OF LINECROSS, TOPCROSS AND BOTTOMCROSS PROGENY WEIGHTS FROM MID-PARENT EXPECTATION[1] FOR CROSSES OF SPECIFIC PARENT INBRED LINES AND OUTBRED GROUP

Breeding of sire	Breeding of dam[2]								
	W	Mi4	Mi7	G2	G5	G22	G25	Wtd. Ave.	Outbred
				(Linecrosses)					(Topcrosses)
W	—	20.2[3]	12.9	17.6	22.3	−13.3	9.9	17.0	15.5
Mi4	12.0	—	12.5	10.9	3.8	−10.5	12.5	8.4	11.5
Mi7	17.0	14.8	—	9.7	16.8	4.5	2.7	14.3	7.8
G2	26.5	21.2	20.2	—	4.5	−10.1		17.6	12.7
G5	14.2	15.1	13.1	7.9	—	5.7	19.9	14.0	4.7
G6	27.2	16.1	12.5	10.9	15.4			17.7	9.9
G22	3.2	6.6	9.8		−7.5	—	−2.2	3.2	−24.3
G25	14.4	12.8	10.4	−24.5	14.0		—	11.5	2.1
Wtd. Ave.	15.4	16.1	13.2	6.4	12.3	−3.4	10.4	13.3**	
				(Bottomcrosses)					
Outbred	16.0	14.2	15.4	13.3	1.4		0.9		9.1**

[1] Mid-parent expectation equals half the sum of the average body weights of component inbred lines (or outbred group) entering each specific cross.
[2] Dam-line G6 not used in crossing; omitted from table.
[3] Unweighted deviation from mid-parent.
** Probability <.01.

weights for lines used in a series of crosses as the common sire-line or as the common dam-line. The order of average linecross progeny performance was similar to the order of inbred line's own performance

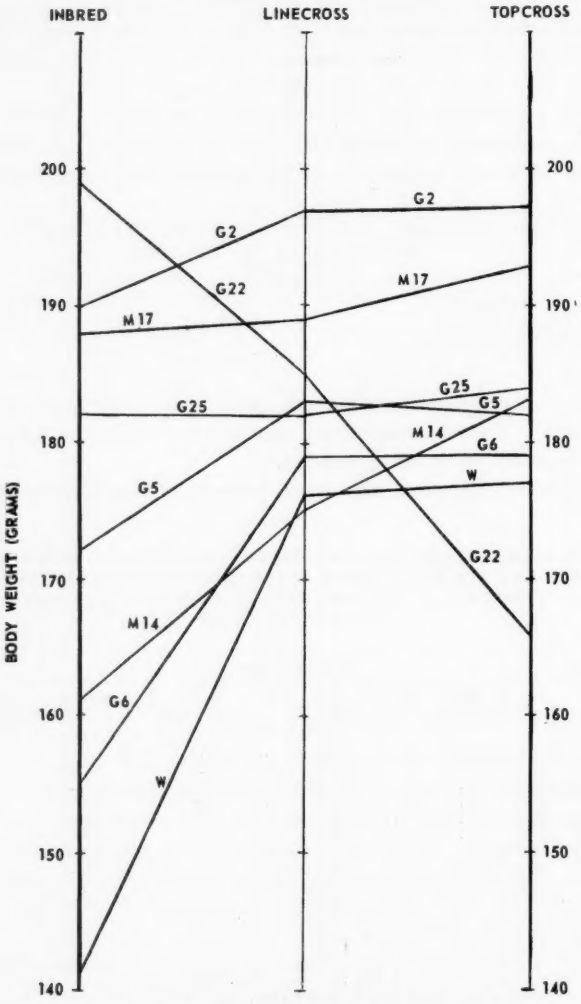


Figure 1. Comparative Thirteen Week Individual Body Weights of Inbred, Linecross and Topcross Progenies Classified by Line of Sire.

although the magnitude of such differences was reduced (figures 1 and 2). Line G22 appears to deviate from this general trend.

Linecross progenies were heavier than inbred progenies by a highly

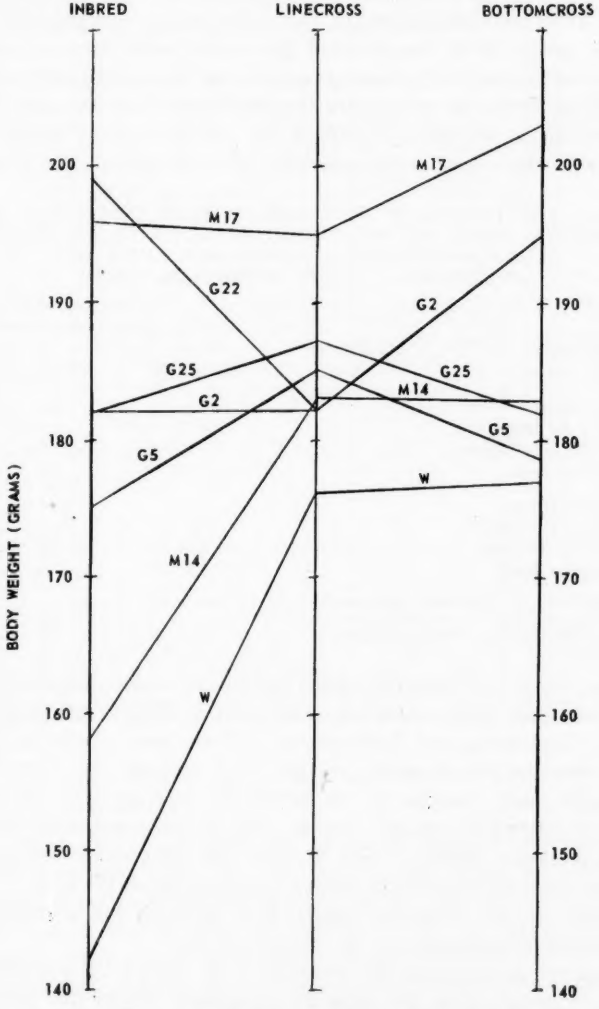


Figure 2. Comparative Thirteen Week Individual Body Weights of Inbred, Linecross and Bottomcross Progenies Classified by Line of Dam.

significant amount when compared with either the component inbred sire-lines or the component inbred dam-lines used in the series of crosses. Crosses of specific lines were significantly heavier by 13.3 gm. than the computed mid-parent weights (table 3).

An arbitrary classification of lines into heavy, medium and light weight groups shows the effects of linecrossing when lines are crossed with others of the same weight group or with lines of dissimilar weight groups (table 4). It is observed that deviations from the mid-parent expectation do not differ greatly for the various kinds of crosses and appear to show a generally beneficial effect of hybridization for all

TABLE 4. DEVIATIONS OF LINECROSS 13-WEEK INDIVIDUAL BODY WEIGHTS FROM THE MID-PARENT EXPECTATION AND FROM THE HEAVIER PARENT LINE WHEN LINES ARE CLASSIFIED AS HEAVY, MEDIUM OR LIGHT

Matings by weight groups[1]	Number of crosses	Average weighted deviations from	
		Mid-parent	Heavier parent
Similar Groups			
Heavy by Heavy	5	10.9±4.19	7.1±4.39
Medium by Medium	2	17.1±5.92	13.1±5.92
Light by Light	4	17.3±2.59	9.5±2.78
Dissimilar Groups			
Heavy by Medium	10	9.1±2.37	0.5±2.57
Light by Medium	9	14.0±1.76	1.3±1.95
Heavy by Light	14	13.3±1.67	−8.1±2.02

[1] Heavy—Mi7, G2, G22—182.4–198.7 gm.
Medium—G5, G25 —172.2–181.6 gm.
Light—W, Mi4, G6 —140.9–160.9 gm.

crosses. Deviations from the heavier parent lines differ sharply depending on whether lines crossed are of the same or different weight groups.

(d) *Topcrossing and Bottomcrossing.* There were significant differences between the topcross progenies and between the bottomcross progenies when classified by the inbred line entering each cross. The general order of performance was the same for topcross and for bottomcross progenies (figures 1 and 2). Also the order of performance of topcross and of bottomcross progenies was similar to the order of performance of the component inbred lines although the magnitude of differences was reduced for the cross-progenies.

Topcross and bottomcross progenies were heavier by a highly significant amount than the respective component inbred line progenies when tested against the interaction of line by mating system as error

term. Topcross and bottomcross progeny were also heavier by a highly significant amount than the mid-parent (table 3). The average increase over the mid-parent was 9.1 gm. Topcross and bottomcross progenies closely approached, on the average, the weight of the heavier parental group (inbred line or outbred group) entering each cross.

TABLE 5. REGRESSION OF SPECIFIC LINECROSS AND OF SPECIFIC TOPCROSS AND BOTTOMCROSS PROGENY BODY WEIGHTS ON THE AVERAGE MID-PARENT[1] BODY WEIGHT, ON THE AVERAGE BODY WEIGHT OF THE HEAVIER PARENT LINE (OR OUTBRED GROUP) AND ON AVERAGE BODY WEIGHT OF THE LIGHTER PARENT LINE (OR OUTBRED GROUP)

Mating system & independent variable	Number of lines[2]	Number of specific crosses	Weighted regression	Probability of regression		Weighted correlation of observed with expected
				Minimum d.f.[3]	Maximum d.f.[4]	
Linecrosses						
Mid-parent	7	39	.71	.03	<.01	.79
Heavier parent	7	39	.62	.09	<.01	.70
Lighter parent	7	39	.44	.14	<.01	.63
Topcrosses and Bottomcrosses						
Mid-parent	9	14	.60	.05	.03	.67
Heavier parent	9	14	1.11	.04	.02	.69
Lighter parent	9	14	.32	.10	.06	.57

[1] Mid-parent expectation equals half the sum of the average body weights of component inbred lines (or outbred group) entering each specific cross.

[2] The number of inbred lines involved in crossing with the outbred group considered as one variable in the topcross and bottomcross groups.

[3] Probability based on degrees of freedom equal to the number of inbred lines (plus the outbred group as one variable in topcrossing and bottomcrossing) minus two.

[4] Probability based on degrees of freedom equal to the geometric mean of the number of inbred lines (plus the outbred group as one variable) and the number of specific crosses, minus two.

Predicting Body Weights of Specific Topcross, Bottomcross and Linecross Progenies

Three different estimates of body weights of progenies from crosses of specific lines were compared with the observed results by regression of observed on predicted results. One estimate was the average of the inbred parent line weights (mid-parent). The mid-parent estimate assumes additive gene action; however, predictability from such a basis is possible when other forms of gene action are present. The other estimates were based on the weight of the heavier parent line and on the weight of the lighter parent line entering each cross. It was postulated

that the heavier line entering each specific cross might have more predictive value than the lighter line of the cross because of some degree of dominance of genes for heavier weights occurring with higher frequency in the heavier line.

All three methods of estimating specific linecross results were effective as shown by the tests for significance of the regressions of observed on predicted body weights (table 5). Significant regressions of combined topcross and bottomcross body weights on the three estimates were also found. The relative degree of success in prediction is indicated by comparisons of the correlations for mid-parent, heavier parent and lighter parent progeny weights with the observed linecross progeny weights respectively. The same comparisons may be made for the topcross and bottomcross data. These correlations show no clear evidence of differing from one another within the linecross and within the topcross and bottomcross data. Neither were differences apparent for the linecross as compared with the combined topcross and bottomcross results on the basis of these correlations.

Predicting Average Combinability of Lines

Line's own performance, line's performance in topcrosses and bottomcrosses, line's performance in testcrosses with a light tester line (Mi4) and in testcrosses with a heavy tester line (Mi7) were all utilized in predicting the average outcome from using lines in a series of linecrosses (table 6). Line's own performance was used in predicting topcross and bottomcross performance for combined topcross and bottomcross data (table 6).

All methods tested gave regressions that were significant or approached significance. Correlations of each of the several bases of estimation with the observed results were all of approximately the same magnitude indicating that no one method was distinctly superior to the others.

Heritability Estimates

Heritability estimates were calculated on the basis of body weight data collected on outbred animals maintained without conscious selection over the period of this study. The standard deviation of body weight, on a female basis, was estimated to be 20 gm. Thirty-nine sire-progenies involving 572 offspring were used in an analysis of variance scheme with separation of variance components as outlined by Fisher (1946). This analysis yielded an estimate of genetic variance between individuals of 42 percent. Most of this variance is taken to be the

result of gene action assigned to the additive scheme. Two other samples of data involving 80 intrasire daughter-dam pairs and 81 intrasire son-dam pairs were used for heritability estimates. Average regressions from these paired observations yielded a heritability estimate of about 50 percent.

TABLE 6. REGRESSION OF THE AVERAGE BODY WEIGHTS OF A SERIES OF LINECROSSES ON THE AVERAGE BODY WEIGHTS OF LINE OF SIRE, LINE OF DAM, TOPCROSS (TX), BOTTOMCROSS (BX), TESTCROSS TO A LIGHT TESTER LINE (LT) AND TESTCROSS TO A HEAVY TESTER LINE (HT). REGRESSION OF COMBINED TOPCROSS AND BOTTOMCROSS PERFORMANCE ON LINE OF SIRE OR DAM

Independent variable	Number of lines[1]	Number of specific crosses	Weighted regression	Probability of regression	Weighted correlation observed with expected
			(Linecrosses)		
Line of sire	7	39	.27	.02	.84
Line of dam	7	39	.24	.02	.83
TX by sire line	7	39	.70	.02	.82
BX by dam line	7	39	.60	.02	.84
LT by sire line	6	26	.58	.01	.96
LT by dam line	6	26	.80	.10	.73
HT by sire line	6	26	.62	.02	.87
HT by dam line	6	26	.29	.32	.50
			(Topcrosses and Bottomcrosses)		
Line of sire or dam	8	14	.29	.05	.66

[1] The number of lines involved in crossing. Line G6 removed from data to give balance to the number of crosses in the paired regressions and correlations.

Discussion

Because of the long generation interval and small numbers usually encountered in large animal research the animal breeder must draw upon genetic theory and on the results of experimentation with plants and laboratory animals as well as with livestock in deciding upon breeding methods most likely to succeed. In other words, a tacit assumption is made that the similarities in the fundamental mechanics of inheritance allows transfer of information from one species to another.

In this study body weight of the laboratory rat is thought of as a representative quantitative character of relatively high heritability (40–50 percent), and one that may reflect the effects of different mating systems in such a way as to add to the general pool of knowledge

concerning the expected relationships between the results of inbreeding, topcrossing, bottomcrossing, testcrossing and linecrossing in livestock breeding.

Cross-progeny body weights for specific crosses between inbred lines and between inbred lines and outbred stock were found to be predictable as shown by generally significant regressions on the average body weight of the parents (inbred lines or inbred line and outbred group), on the heavier parent and on the lighter parent. Average or general combining value of lines used in a series of crosses was also found to be predictable from line's own performance, from topcross and bottomcross performance and from testcross performance with either a heavy or a light inbred tester line.

Corn breeders have consistently found positive, small and usually significant correlations between yield of inbred lines based on the average of the parent lines and their individual hybrids. Richey (1950) points out that:

> "Such correlations involve not only the average value of the germ plasm, but also the way that different genetic complements may or may not nick. But, Jenkins (1929, table XIII) reported correlations also for the yields of individual inbreds with the mean yields of their several crossbred progeny. Such mean yields tend to average out nicking effects and measure the average combining value. These correlations, naturally, tended to be much higher."

Specific combining ability or "nicking" appeared to be relatively unimportant in this experiment. Correlations of the average body weight of the component inbred lines (mid-parent) with the individual linecross progeny body weights were about as large as the correlations of inbred line's own performance with the average performance of the line in a series of crosses. Furthermore, the average linecross performance of each line was predicted with a high degree of accuracy from its testcross performance.

The inbred-variety cross in corn and the topcross in livestock are tests which are being used for preliminary evaluation of a line's average or general combining ability, Sprague (1946), Richey (1950), Hazel *et al.* (1948) and Durham *et al.* (1952). The results of the present study showed line's own performance to be as reliable as topcrossing for indicating the relative value of inbred lines in a series of crosses. Line's own performance, however, gives no indication of the amount of hybrid vigor likely to be obtained in crossing as do crossing tests.

The high heritability of this character implies that consistent selection

for high or low body weight has not been practiced in the past history of these rats. This character would therefore be looked on as differing from those characters, such as prolificacy and viability, discussed by Dickerson (1952) and Henderson (1949) in swine and by Eaton *et al.* (1950) in mice, in which the low heritability found could have resulted from consistent positive selection and consequent fixing of the major part of the genic variation. The specific combining ability found for prolificacy and viability by these workers would, of course, lead to poor predictability from line's own performance (mid-parent) to specific crosses and from testcrosses to general outcome in linecrosses, topcrosses and bottomcrosses.

Hybrid vigor was obtained in this experiment, as indicated by body weights of specific cross-progenies which exceeded the average of the two parent lines (or inbred line and outbred group) and equalled, on the average, the weight of the heavier inbred line entering each cross. Genetic action responsible for cross-progeny weights in excess of the mid-parent weight is obviously non-additive and is unlikely to be epistatic because of the generally consistent positive deviations found here (table 3). It appears therefore that some degree of dominance and/or overdominance of genes affecting body weight was responsible for the hybrid vigor. The lack of an inbreeding depression effect for the five lines derived from and compared with the outbred stock in this experiment is difficult to explain except on the basis of chance segregation of lines with heavy body weight in a higher frequency than would be expected on the average or if a larger number of lines had been formed.

Whether the cross-progeny of any particular combination of lines (or of line and outbred group) exceeded the performance of the better parent appeared to depend on how similar the component lines were in their own phenotypes (table 4). The beneficial effect of crossing appeared to be of approximately the same magnitude with reference to the mid-parent for each of the crosses of a particular line so that the cross-progeny of matings of parent lines of similar size exceeded the heavier parent line but did not exceed the heavier parent line where dissimilar matings were made.

The lines used in this experiment varied considerably in inbreeding with five being crossed at levels of .25 and .375. Despite this low level of inbreeding there were significant differences between the inbred progenies of these lines (inbreeding of .375 and .50) and between the groups of cross-progenies produced. Sprague (1952) has summarized

the corn experiments bearing on the value of early testing and has concluded that lines showing particularly poor combining ability at low levels of inbreeding may be discarded with small likelihood of losing valuable lines.

On the basis of these results it would appear most efficient for the breeder of livestock dealing with a character similar to 13-week weight in rats to cull undesirable lines at low levels of inbreeding so that facilities would be released for the development of other potentially more valuable lines. Line's own performance should be of considerable value in indicating which lines should be culled and which lines should be carried on and tested further in crossing.

Topcrossing and testcrossing (the latter with a highly inbred tester line), although about equally effective for indicating the relative value of different lines for crossing as line's own performance in this experiment, had the added advantage of indicating the amount of hybrid vigor likely to be attained. Topcrossing would in general, however, have the advantage over testcrossing, even where specific combinability is not important, because it does not necessitate the maintenance of a highly inbred line useful only as a tester.

Summary

Heritability of 13-week individual body weight in rats was estimated to be 40–50 percent. The standard deviation for body weight in the individual outbred rat (female basis) was estimated to be about 20 gm. Litter size, litter sequence, sex-linked genes and maternal influence were found not to be important sources of variation in adult body weight.

Differences between sire progenies within lines and within mating systems (inbreeding, topcrossing and linecrossing) were found to be generally lacking in significance.

Inbred lines derived from the same outbred foundation stock were found to diverge significantly from each other. No general loss of vigor, as measured by body weight, was evident when the average body weight of these inbred lines was compared with outbred stock maintained from the same source material. Differences between inbred lines were reflected by similar differences between their progeny produced by crossing with the outbred stock and by crossing with a series of other inbred lines.

Crossed progeny (topcross, bottomcross and linecross) were found to be significantly heavier on the average than the component inbred

lines from which they were derived. They did not, on the average, exceed the body weight of the heavier parent line (or outbred group) entering each specific cross.

Linecross progeny body weights from the crossing of specific inbred lines were found to be predictable as indicated by significant regressions on the average body weight of the parent lines, on the body weight of the heavier lines, and on the body weight of the lighter lines entering each cross. Significant regressions of topcross and bottomcross body weights on these three estimates were also found where the outbred group served as one parent in each cross. These three methods were found to be of about equal value.

The relative value of inbred lines for crossing with other inbred lines was found to be predictable from line's own performance. Line's performance in topcrossing and bottomcrossing and line's performance when testcrossed with highly inbred "tester" lines indicated average combining value and the amount of hybrid vigor likely to be obtained on the average. Comparisons of correlations of the observed body weights and the expected body weights for these methods showed no clear-cut evidence of differences in their effectiveness in prediction. Dominance and/or overdominance were apparently responsible for the hybrid vigor observed in cross-progenies.

Literature Cited

Dickerson, G. E. 1952. Heterosis. Chapter 21, Iowa State College Press, Ames, Iowa.

Durham, R. M., A. B. Chapman, and R. H. Grummer. 1952. Inbred versus non-inbred boars used in two sire herds on Wisconsin farms. JOURNAL OF ANIMAL SCIENCE 11:134.

Eaton, O. N., W. E. Neville, and G. E. Dickerson. 1950. General and specific combining abilities in mouse crosses. JOURNAL OF ANIMAL SCIENCE 9:636. (Abstract)

Fisher, R. A. 1946. Statistical methods for research workers. Tenth Edition. Oliver & Boyd Ltd., Edinburgh.

Haze[1], L. N., A. L. Musson, and J. L. Lush. 1948. Comparisons of inbred Poland China, Landrace and purebred boars on Iowa farms. JOURNAL OF ANIMAL SCIENCE 7:512. (Abstract)

Henderson, C. R. 1949. Estimation of general, specific, and maternal combining abilities in crosses among inbred lines of swine. JOURNAL OF ANIMAL SCIENCE 8:606.

Kyle, W. H. and A. B. Chapman. 1953. Experimental check of the effectiveness of selection for a quantitative character. Genetics. In Press.

Lush, J. L. 1947. Biometrics 3:54.

Richey, F. D. 1950. Corn breeding. Advances in Genetics 3:159. Academic Press Inc., New York, N. Y.

Snedecor, G. W. 1946. Statistical methods applied to experiments in agriculture and biology. Fourth Edition. Iowa State College Press, Ames, Iowa.

Sprague, G. F. 1946. The experimental basis for hybrid maize. Biol. Rev. 21:101.

Sprague, G. F. 1952. Heterosis. Chapter 26. Iowa State College Press, Ames, Iowa.

ENVIRONMENTAL FACTORS AFFECTING BODY SIZE AND CONFORMATION IN RAMBOUILLET YEARLING EWES[1]

DANIEL W. CASSARD, P. W. GREGORY, J. F. WILSON, W. C. ROLLINS, W. C. WEIR

University of California[2]

BODY conformation and size are ordinarily given considerable weight in the selection of breeding animals in meat producing species. The fact that the phenotype of an animal for size and conformation is a result both of genetic potentialities and the influence of environmental factors leads to inaccuracies in the assessment of its real genetic worth. In addition, the conventional method of visually evaluating the animal on the basis of its total appearance leads to further difficulty due to inability of an observer to be consistent over periods of time and with different types of animals and flocks. Inability to give consistently the same weight to the many considerations involved in such evaluations is an added difficulty. It would therefore seem desirable to develop more objective means of describing and evaluating size and conformation.

The present study was undertaken with the idea of finding how to adjust body measurements for environmental effects in order to use them most effectively in describing size and conformation of Rambouillet sheep.

Hazel and Terrill (1945) have shown that type of birth (twin vs. single), age of dam, sex, age, and inbreeding had significant effects on the weaning weight of Rambouillet lambs. They also found (1946) that in yearling ewes these effects were less important—that is, they had been overcome to some extent. A number of other workers have shown these effects to be important in other breeds of sheep (Donald and McLean (1935), Phillips and Dawson (1937), Bonsma (1939), Terrill, Sidwell and Hazel (1947, 1948) but they have not been studied on objective measurements other than weight.

Data and Results

The data available for this study were collected in the Rambouillet flock at the University of California at Davis from 1936 to 1949. A series of body measurements, including weight, heart girth, round

[1] This work was supported by the Kellogg Fund for application of genetics to farm mammals.
[2] Agricultural Experiment Station, Davis.

measurement, (the horizontal distance from patella to patella around the posterior end of the animal) chest depth and width, loin width and height at withers, was taken by one of us (P.W.G.) at shearing time which was usually early in April. Weight was taken on a normal fill to the nearest pound. Heart girth and round measurements were taken with a corded linen tape, and all other measurements were taken with calipers specially designed for the purpose. The data included measurements on 135 animals averaging 475 days in age. Since very few males were saved to this age, making those which were measured a highly selected group, it was decided to include only the females. Although a few inbred animals are included, the average coefficient of inbreeding for the group was only about 1 percent and it did not appear practical to include the effect of inbreeding in the investigation. The distribution of the data according to years, type of birth, and age of dam is shown in columns 1 and 2 of table 1. By referring to columns 3 and 4, it can be seen that the number lost between birth and measuring time is not much more than would be expected due to normal mortality; thus, this is a relatively unselected group. Sires are listed in the last column and it can be seen that, with the exception of A7986 and 1244RW, each sire was used only one year, so that the effects of sire and year are confounded and cannot be estimated separately in these data.

It would have been possible to evaluate effects of type of birth, age, age of dam, and years simultaneously by the method of Hazel (1946). However, with thirteen year-effects involved, and the limited numbers in these data, it would be too laborious to be practical. Accordingly, it was decided to evaluate the age effect separately. For this purpose, a within-years, within-type-of-birth, within-age-of-dam pooled regression of each measurement on age in days was calculated. Included were 126 animals in the 35 subgroups of columns 1 and 2, table 1 containing 2 or more animals. The resulting pooled regressions are given in the first column of table 2. Regressions of weight, loin width, and heart girth are significantly different from zero at the 1 percent level, while those in chest depth and width and round measurement are significant at the 5 percent level. Height growth has apparently ceased, since the regression on age is very small and non-significant. It is apparent that growth in all measurements has leveled off considerably, as the observed regressions are too small to account for the observed means at this age on a straight line basis. Homogeneity tests showed no indication of differences among the sub-group regressions pooled, so these pooled estimates seem the best correction factor available for age. Accordingly,

they were used to adjust all data to the average age of 475 days. The proportions of variance removed are given in table 2, and from them it is seen that the effect of age on all measurements except height at withers is important enough so that it should be taken into account if they are to be used accurately for selection purposes.

In order to evaluate the effect of type of birth and age of dam, it

TABLE 1. DISTRIBUTION OF RAMBOUILLET FEMALES

Year		1 Mature dam	2 2-year old dam	3 Total measured as yrlgs.	4 No. born alive	5 Sire
1936–37	twin	4	6	13	17	DL3225
	single	3	0			
1937–38	twin	2	2	9	14	AM2717
	single	2	3			
1938–39	twin	5	5	12	14	A7986
	single	0	2			
1939–40	twin	4	0	10	12	A7986
	single	5	1			
1940–41	twin	4	1	7	8	MSC820
	single	1	1			
1941–42	twin	5	3	13	13	JKM3864H
	single	2	3			
1942–43	twin	13	2	18	18	250RW
	single	2	1			
1943–44	twin	7	3	15	15	D38
	single	2	3			
1944–45	twin	2	1	11	12	1244RW
	single	3	5			
1945–46	twin	4	0	5	5	837RW
	single	1	0			
1946–47	twin	4	0	8	8	UC3286
	single	4	0			
	twin	1	0	1	3	1244RW
1947–48	twin	2	0	5	5	UC3427
	single	3	0			
1948–49	twin	3	2	8	10	1719RW
	single	1	2			
Total twins		60	25	85	154	
Total singles		29	21	50		
GRAND TOTAL		89	46	135		

TABLE 2. ESTIMATES OF ENVIRONMENTAL EFFECTS ON MEASUREMENTS AND VARIANCE PROPORTIONS ASSOCIATED WITH THEM

A.

Measurement	Regression on age in days	Percent var. removed[1]	Single minus twin	Percent var. removed[1]	Mature minus 2-yr. old dam	Percent var. removed[1]	Sum all var. removed[1]	Percent var. assoc. w/ Sires-yrs.[4]	Adjusted mean	Within-years stand. dev.
Withers ht. cm.	.0001	0	1.9**	18.9	.6	0	18.9	14.8	66.95	2.53
Chest depth cm.	.0276*	6.8	0.8**	8.3	.1	0	15.1	33.5	29.47	1.33
Chest width cm.	.0337*	6.6	1.3**	18.1	.5	0	24.7	27.6	20.69	1.56
Loin width cm.	.0184**	10.01	0.6**	12.9	.1	0	22.9	47.0	13.34	0.72

B.

			Twins only		Singles only		After dam-age adjustment				
Measurement	Regression on age in days	Percent var. removed[1]	Mature minus 2-yr. old dam	Percent var. removed[2]	Mature minus 2-yr. old dam	Percent var. removed	Single minus twin	Percent var. removed[3]	Percent var. assoc. w/ Sires-yrs.[4]	Adjusted mean	Within-years stand. dev.
Heart girth cm.	.0760**	10.0	3.2*	14.2	—1.1	0	1.4	0	65.5	85.12	3.06
Round meas. cm.	.0349*	4.5	3.7**	19.4	—0.4	0	0.4	0	83.5	48.92	2.26
Body weight lbs.	.2445**	7.4	9.4*	10.1	—2.7	0	6.6*	5.8	60.4	118.65	10.81

[1] All variance proportions as % of variance in original raw data.
[2] Variance proportions as % of variance in twins group after age correction.
[3] Variance proportion as % of variance remaining after age and dam-age corrections.
[4] Variance proportion as % of variance remaining after adjusting to 475 days, single, mature dam status.
* Indicates significance at 5% level.
** Indicates significance at 1% level.

seemed best to combine the data for all the years of the study. The distribution thus obtained is that at the bottom of table 1. Scrutiny of the sub-class means in the age-adjusted data gave no indication of any interaction between years and either of the main effects of interest, so it appeared that no serious error would be involved in combining the years. The age-of-dam and type-of-birth effects were estimated by the analysis of variance method of "fitting constants" of Yates (1934). The estimates obtained and the variance proportions associated with them are given in table 2A for withers height, depth and width of chest, and loin width. In all four of these measurements, the effect of type of birth was highly significant and accounted for an important part of the variance in the measurements. In none of these was the effect of age of dam significant. In heart girth and round measurement, an interaction significant at 5 percent level was found between the two main effects. Since in this method such an interaction makes estimates of the effects meaningless, it was necessary instead to consider the twins and singles as separate groups and use a one way analysis of variance within each group to estimate the age-of-dam effects in these measurements. Because the interaction test was close to significance for body weight, and because examination of sub-class means in weight seemed to indicate it should be considered with heart girth and round rather than with the other four measurements, it was included in this group. Analysis of variance for age-of-dam effect in the singles group revealed none in any of the measurements. However, twins from two-year-old dams were smaller than twins from older dams. This difference was highly significant in round measurement and significant in heart girth and body weight. After adjusting all data to mature-dam status, it was found that there was a significant difference in body weight due to type-of-birth, but none in the other two measurements. Apparently in heart girth and round measurement the twins from two-year-old dams are slightly smaller, the twins from older dams and all singles being about the same size.

Although the effects of years and sires could not be separated, it seemed important to find out what proportion of the variance in the measurements was associated with these combined effects. Accordingly, the data (already corrected to 475 days age) were adjusted to mature dam, single status and an analysis of variance on the adjusted data showed year-sire effects highly significant in all measurements. Variance proportions associated with them are given in table 2. As would be expected, these are important sources of variance in all the measure-

ments. In the four measurements given in the A part of the table 2, all variance proportions given except that for years and sires have been calculated as proportions of the original variance in the raw data. In the three measurements in table 2B where the twins and singles were considered separately and then combined, there appears to be no method available for reducing the variance proportions to a comparable basis. Therefore, the percentages reported refer to the variance remaining in the data used for the respective estimates (see footnotes). In both A and B parts of the table, variance proportions for years and sires are on the basis of the remaining variance in adjusted data, for purposes of comparison between measurements. The last two columns in table 2 give the mean after adjusting to 475 days, single and mature dam status, and the within years standard deviation in each measurement. These can be considered as population statistics and give a point of reference for comparisons in breeding programs.

Discussion

The results reported above seem to indicate quite clearly that a worthwhile gain in accuracy is to be made by correcting body measurements studied, (except withers height) for age in days in animals about 16 months old. In the case of animals born as twins, an adjustment is necessary for age-of-dam in heart girth, round, and body weight, while none is needed for singles or in the other measurements. All measurements except heart girth and round should be adjusted for type of birth (twins vs. single).

In these data, sire and year effects were confounded, but their joint influence was an important source of variation. If this is mainly sire difference, it is very important in selection, while if it is mainly due to yearly environmental fluctuations, it should be removed. In designing breeding programs therefore, it would seem important to use sires more than one year, and use several sires in order to have some means of separating these effects.

Gregory (1933), Knapp and Cook (1932) and others have used withers height as a measure of skeletal development in cattle. Lush (1928) found that in fattening steers increases in chest width and loin width were relatively high. Perhaps changes in these measurements are a measure of fatness. Gregory (1933) used round measurement as an indication of thickness of muscling, even though it is also influenced to some extent by degree of fatness. Body weight and, to a lesser extent, heart girth, are in general used as indicators of overall body size. The

investigations mentioned give some ideas to what changes in measurements represent, but clearer relationships to economic characters need to be established.

Summary

Body measurement data obtained from the University of California purebred Rambouillet flock were studied to learn the importance of known environmental sources of variation, and to find whether a worthwhile gain in accuracy in the use of measurements would be made by adjusting for these effects.

The data include the following measurements on 135 females born from 1936 to 1948, averaging 475 days in age; withers height, depth and width of chest, loin width, heart girth, round measurement and body weight.

It was found that difference in age was an important source of variation in all measurements studied except withers height, in which full growth had apparently been attained. Twins were found to be smaller than singles in all measurements except heart girth and round measurement, while twins from 2-year-old dams were smaller in body weight, heart girth and round than twins from older dams. Dam-age did not affect other measurements. Combined effects of sires and years were found very important, but these could not be estimated separately. It is concluded that a considerable gain in accuracy for selection purposes can be made by standardizing body measurements with regard to the environmental effects estimated.

Literature Cited

Bonsma, F. N., 1939, Factors influencing the growth and development of lambs with special reference to cross breeding of Merino sheep for fat-lamb production in South Africa. Univ. of Pretoria Publications Series 1, Agr. No. 48. 214 pp.

Donald, H. P. and J. W. McLean. 1935. The growth rate of lambs in Canterbury. N.Z. Jour. Sci. and Tech. 17:497.

Gregory, P. W. 1933. The nature of size factors in domestic breeds of cattle. Genetics 18:221.

Hazel, L. N. 1946. A note on the covariance analysis of multiple classification tables with unequal subclass nos. Biometrics Bulletin 2:21.

Hazel, L. N. and C. E. Terrill. 1945. Effects of some environmental factors on weanling traits of range Rambouillet lambs. JOURNAL OF ANIMAL SCIENCE 4:331.

——— 1946. Effects of some environmental factors on fleece and body characteristics of range Rambouillet yearling ewes. JOURNAL OF ANIMAL SCIENCE 5:382.

Knapp, B. Jr. and A. C. Cook. 1932. A comparison of body measurements of beef and dual purpose cattle. Amer. Soc. An. Prod. Proc. 1932:77.

Lush, J. L. 1928. Changes in body measurements of steers during fattening. Texas Agr. Exp. Sta. Bull. No. 385. 59 pp.

Phillips, R. W. and W. M. Dawson. 1937. The relation of type and time of birth and birth weight of lambs to their survival, growth and suitability for breeding. Amer. Soc. An. Prod. Proc. 1937:296.

——— 1940. Some factors affecting survival, growth and selection of lambs. U.S.D.A. Cir. 538. 18 pp.

Terrill, C. E., G. M. Sidwell and L. N. Hazel. 1947. Effects of some environmental factors on yearling traits of Columbia and Targhee ewes. JOURNAL OF ANIMAL SCIENCE 6:115.

——— 1948. Effects of some environmental factors on yearling traits of Columbia and Targhee rams. JOURNAL OF ANIMAL SCIENCE 7:181.

——— 1948. Effects of some environmental factors on traits of yearling and mature Rambouillet rams. JOURNAL OF ANIMAL SCIENCE 7:311.

Yates, F. 1934. The analysis of multiple classifications with unequal numbers in the different classes. Amer. Stat. Assn. Jour. 29:51.

SELECTING LAMBS UNDER FARM FLOCK CONDITIONS[1]

H. A. KARAM,[2] A. B. CHAPMAN and A. L. POPE
University of Wisconsin[3]

IT has been shown that selection for at least the additively genetic part of the variation, when considering more than one character per individual, can be done most efficiently by selecting for the characters simultaneously (Hazel and Lush, 1942). Schemes for giving effect to this "total score" or "index" type of selection were first developed by Smith (1936) and Hazel (1943).

The purpose of the present study was to suggest an index for selecting lambs for replacements in farm flocks. The data available from the farm flock records collected for this study did not furnish all the estimates required, but with the help of statistics reported by other workers, the construction of a preliminary index was possible.

The Data

The data used in this study were taken from records collected from 1944 to 1949 on a breeding project conducted in cooperation with Wisconsin farmers. Each year the Experiment Station leased purebred Shropshire rams to these farmers who were grade sheep producers. The rams had been purchased from purebred breeders who sold Shropshire rams extensively in Wisconsin. In large flocks two rams were used. The ewes were divided between the rams essentially at random. The general scheme followed for the first four years was to transfer each ram to another flock in the fall. In 1948 and 1949 all the flocks except two were two-sire flocks and the rams were dialleled within the same flock, i.e. each ram was bred to the group of ewes which had been mated to the other ram the previous year.

The plan was to purchase a restricted random sample of eight lambs per sire each year. These included two of each combination—ewe singles, ewe twins, wether singles and wether twins—from each sire, with each twin lamb having been born and raised as a twin and each twin from a different ewe. In some cases the numbers and classifications of

[1] Paper No. 499 from the Departments of Genetics and Animal Husbandry, University of Wisconsin.

[2] Present address: College of Agriculture, Alexandria, Egypt.

[3] The authors wish to thank Dr. C. R. Henderson, Animal Husbandry Department, Cornell University, for his valuable assistance with the statistical analysis. They also appreciate the help of Mr. B. Winchester, co-leader of the project from 1944–46.

the lambs per sire were not as planned due mainly to death of the lambs before all records were obtained. The lambs were weighed on the farms at an average age of 155 days (standard deviation=31.5 days) and at that time they were brought to the University where they were drenched and placed on feed in separate lots by sire progeny groups.

The lambs were kept on feed until the body weight of the entire group averaged between 80 and 90 pounds. The lambs averaged 247 days when they were taken off feed, at which time they were weighed and several body measurements and scores were taken on them. Following this they were sent to the packing plant where additional data were collected. Staple length was measured in 1948 and 1949 only. The average age of the lambs for these two years was 239 days at the time of slaughter. Body weight and face covering scores were taken on 593 lambs from 27 sires in 16 different flocks. Data on staple length were taken on 180 of these lambs sired by 12 rams and raised in seven flocks. Body weight was measured to the nearest pound and staple length to the nearest 0.5 centimeter. Face covering scores were a modification of those used by the Western Sheep Breeding Laboratory (Terrill, 1941). They ranged from 1 to 7 as follows: "1" not covered beyond the poll, "2" covered to the eyes, "3" covered slightly below the eyes but open faced, "4" covered below the eyes, "5" entirely covered below the eyes and subject to wool blindness, "6" almost covered and subject to wool blindness, "7" completely covered and wool blind. The percentages of the lambs in the seven classes, ranging from 1 to 7, are as follows: .84, 3.04. 4.38, 8.26, 18.89, 39.46 and 25.13, respectively.

There is a high degree of non-orthogonality in the data due to the fact that all rams and all flocks were not represented in each year, that many flocks were one-sire flocks and that some sires were not represented equally by progeny in the different types of birth. The disproportionate nature of the distribution is shown in table 1 where the data are classified according to sire and flock.

Results

The relative economic values

The economic value assigned to a character in this study was the relative effect this character is assumed to have on profit when it varies one unit in a flock of a certain size e.g. 100 ewes. It is, further, assumed that the lamb crop weaned averages 125 percent annually from the 80 ewes two years or more of age. The annual replacement rate was considered to be 20 percent on the basis of the records of these project

TABLE 1. THE DISTRIBUTION OF THE DATA CLASSIFIED ACCORDING TO SIRE AND FLOCK

Flock \ Sire	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	20	21	22	25	27	30	31	32	33	Total
1	8	6				7	5																					26
2	8		16		6											15		7		7								59
3			7				6	8		8																		29
4			8	7						16	7								8				16					62
5	8			8		7											8											31
6				8	4									6														18
7	23			16			8		21	8	7						7											90
8																	8											8
9			8				8	15							7				8									46
10					6									8	6			8										28
11																4												4
12				7	8						6	5		8		7		8		8								57
13			7								7		16	6			14					8						58
14																						16						16
16																								15	16			31
17																										16	14	30
Total	47	6	46	46	24	14	27	23	21	32	27	5	16	28	13	26	37	23	16	15	8	16	16	15	16	16	14	593

flocks and in other Wisconsin flocks according to data presented by Krause (1950).

The path diagram in figure 1 illustrates the relationships among the characters considered in this work to have a direct effect on income in

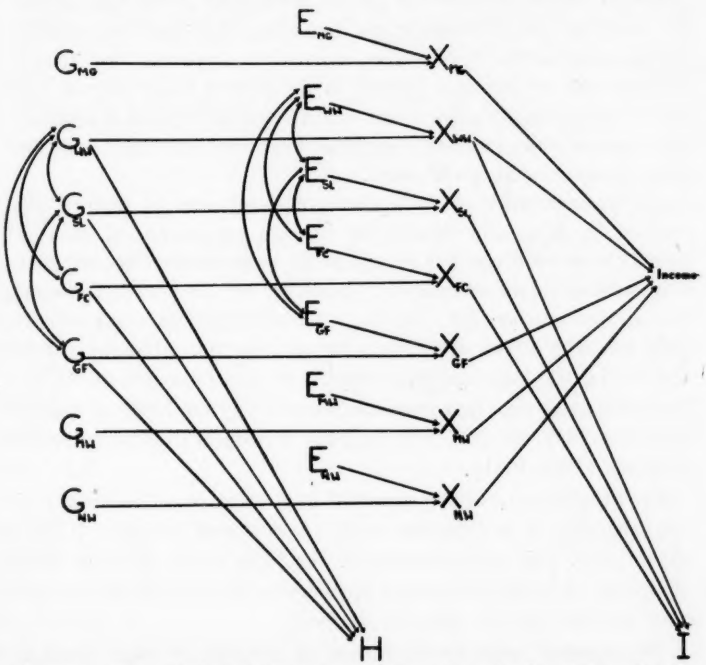


Figure 1. The relationship between income, the selection index (I), the aggregate genic value (H) and the characteristics considered, in this work, to affect income in a farm sheep enterprise. MG, WW, SL, FC, GF, MW and NW are market grade, body weight, staple length and face covering of lamb, grease fleece weight, and body weight of mature ewe, and number of lambs weaned per ewe, respectively. The X's are the phenotypic values, the G's are genic values and the E's are the non-additive genetic effects plus environmental effects for these characters.

a farm sheep enterprise. Bidirectional arrows are shown in the diagram only in those cases in which values were available for use in the index from this or other studies.

There was not enough intraflock variability in other characters, such as fineness of fleece, among the lambs studied in this project to make it appear worthwhile to include them with characters affecting income.

Fleece weight is not available on the lambs themselves at the time they are selected but it can be estimated from weanling body weight and staple length with which it is genetically correlated (Morley, 1950 and Rae, 1950). Number of lambs weaned and mature weight are likewise of economic value but are not measurable at the time of selection and the genetic correlations involving them are not available. Market grade of the lambs is also economically important, but statistics necessary for its inclusion directly in the present index are not available. Hence these three characters were given consideration in estimating the economic values of body weight or face covering and thereby indirectly were included in the index.

The average price of 100 pounds of lamb and of mature sheep received by Wisconsin farmers for the last six months of each year from 1936 to 1950 was $13.04 and $4.90, respectively (Krause, 1950), after subtracting an average of 50 cents per cwt. as cost of transportation and commission fee. The cost of maintaining an extra pound of body weight in a flock of 100 ewes for one year was estimated at $3.80, and on the 100 lambs produced each year was estimated at 50 cents. These estimates were based on data presented by the National Research Council (1945), Brody (1945) and the Wisconsin Crop and Livestock Reporter (1936–1951).

The average price of one pound of wool of ⅜ blood combing (56's) was calculated to be forty-four cents (Agricultural Statistics, U.S.D.A., 1936–1950). This was estimated on the basis of the price per pound, at Boston, of bright fleece wool on a grease basis after subtracting six cents for handling and shipping charges.

The economic value of an increase of one unit in staple length will depend largely on whether all the fleeces are long enough to meet the requirement for the particular grade of wool produced. From the statistics obtained in this study it is likely that there will be enough length in the fleeces, at shearing time, so that extra length within the limits of the amount of variability available per flock, will not be accompanied by an increase in price.

Face covering received its value on the arbitrary assumption that the genetic relationship with number of lambs weaned is the same as the phenotypic relationship between them reported by Terrill (1949).

The relative economic values obtained from the above considerations and used in this study are: body weight 1.0, staple length 0.0, face covering −1.5, and grease fleece weight 4.0.

Means and variances

Table 2 presents means, variances, standard deviations and coefficients of variability for body weights adjusted to 155 days of age, staple length to 239 days and face covering to 247 days for the different types of birth. Means were adjusted for the disproportionate numbers of

TABLE 2. MEANS, VARIANCES, STANDARD DEVIATIONS AND COEFFICIENTS OF VARIABILITY FOR BODY WEIGHT AT 155 DAYS, FACE COVERING AND STAPLE LENGTH, IN EWE SINGLES (E.S.) EWE TWINS (E.T.), WETHER SINGLES (W.S.) AND WETHER TWINS (W.T.)

Character and type of birth	No. of observations	Degrees of freedom[1]	Mean	Variance	Standard deviation	C.V.%
Body wt. at 155 days						
E.S.	145	70	64.1	76.81	8.77	13.7
E.T.	152	78	56.8	82.93	9.11	16.0
W.S.	145	68	67.6	109.73	10.48	15.5
W.T	151	72	59.3	110.51	10.66	18.0
Total	593	288	62.2	94.67	9.73	15.6
Staple length						
E.S.	45	22	6.28	.54	.73	11.7
E.T.	47	24	6.35	.86	.93	14.6
W.S.	46	23	6.35	.74	.86	13.5
W.T.	42	19	5.85	.79	.89	15.2
Total	180	88	6.21	.73	.86	13.8
Face covering						
E.S.	145	70	5.6	1.00	1.00	17.9
E.T.	152	78	5.4	1.08	1.04	19.3
W.S.	145	68	5.7	1.21	1.11	19.5
W.T.	151	72	5.7	1.42	1.19	20.9
Total	593	288	5.6	1.18	1.08	19.4

[1] Within year, flock, sire, and type of birth.

lambs per sire in the different types of birth by using the least squares estimate technique. They were also adjusted for the small differences which occurred in the average ages when the records were taken for the different types of birth. This was done by using the regression of measurement on age calculated within year, flock and sire. Variances were also calculated within year, flock and sire.

Wether lambs and single lambs were significantly heavier than ewe and twin lambs, respectively. Similar results were reported for several

breeds of farm and range sheep by Donald and McLean (1935), Bonsma (1939), Phillips and Brier (1940), Phillips and Dawson (1940), Phillips *et al.* (1940), and Hazel and Terrill (1945a, 1946a).

Differences in staple length were not significant. Hazel and Terrill (1945a, 1946a) reported that ewe lambs and single lambs had longer staple than wether and twin lambs, respectively, in weanling range sheep. Rae (1950) reported that twin ewe lambs had longer staple than singles in the Romney breed.

Differences among types of birth in face covering were not statistically significant. Studies made by Hazel and Terrill (1945a, 1946a, 1946c) and Terrill *et al.* (1947, 1948a, 1948b) on range sheep showed that differences in face covering scores among types of birth were small and inconsistent in the different breeds. Their scores ranged from 1 to 5 with one being not covered beyond the poll and 5 being almost or entirely covered and subject to wool blindness.

Morley (1950) found that variances for body weight among sex-year groups were heterogeneous and that larger variances were associated with larger means, the coefficients of variability being relatively constant. He suggested that this might be due to causes of variation acting in a multiplicative way. In this study variances in body weight of lambs were not significantly heterogeneous between different types of birth but larger variances were associated with the larger means of the wethers as compared with the ewes.

Phenotypic regressions and correlations

Since the observations were taken on lambs varying in age, around averages of 155, 239 and 247 days for the different characters, regression coefficients of measurement on actual age were calculated within year, flock, sire and type of birth. The values obtained were .272, .033 and —.0004 for body weight at an average age of 155 days, staple length at an average age of 239 days and face covering at an average age of 247 days, respectively. The first two were statistically highly significant. They were used to adjust the data to the average ages using the adjusted values (Y—bx) instead of the original observations (Y). b is the regression of the dependent variable on age and x is the deviation of the age of the lamb from the average age of all lambs.

Phenotypic correlations were calculated within year, flock, sire, and type of birth. They were .14 for body weight with staple length, —.13 for body weight with face covering and —.02 for face covering with

staple length. The correlation between body weight and face covering was statistically significant. The others were insignificant. The Western Sheep Breeding Laboratory (1946) reported the following correlations for Rambouillet weanling traits: .15 between body weight and staple length, —.05 between body weight and face covering and .02 between staple length and face covering. Terrill, Kyle and Hazel (1950) found these three correlations to be .07, —.17 and .04 respectively, in yearling Rambouillet rams.

Variance and covariance components

There are several procedures for estimating variance components from non-orthogonal data, but very little is known about the magnitude of the sampling errors of statistics from such data. The method used in this study is described by Henderson (1948 and 1952). It yields unbiased estimates of the components of variance, but does not indicate the efficiency of the estimates.

The method involves computing the various sums of squares as if the data were orthogonal and then finding the expected values in terms of the variances for each of these sums of squares. Then each expected value is equated to its computed value and the resulting set of equations are solved simultaneously for the variances.

The following is the linear mathematical model assumed.

$$Y_{ghijk} = \mu + a_g + f_h + s_i + t_j + bx_{ghijk} + e_{ghijk}.$$

where Y_{ghijk} is a measurement on the kth lamb of the jth type of birth, sired by the ith sire in the hth flock and in the gth year. x_{ghijk} is the age of the individual lamb at the time the measurement was taken, μ is the population mean, a_g is an effect due to the gth year, f_h is an effect due to the hth flock, s_i is an effect due to the ith sire, t_j is an effect due to the jth type of birth, b is the regression of measurement on age and e_{ghijk} is a random error associated with the individual measurement.

There were seven pairs of half-sibs and two pairs of full-sibs among the sires used in this study. Adjustments were made for these relationships in calculating the coefficients of the sire variance and covariance in the expectations of the different sums of squares.

Estimates of the variance and covariance components for the characters studied are presented in tables 3 and 4. Methods for calculating sampling errors of these estimates are not known. The errors are undoubtedly large, however.

TABLE 3. ESTIMATES OF VARIANCE COMPONENTS

Characters	σ_a^2 Year	σ_f^2 Flock	σ_s^2 Sire	σ_t^2 Type of Birth	σ_e^2 Error
Body wt. at 155 days	20.33	91.62	10.34	15.76	112.16
Staple length	0.00	0.21	0.13	0.04	0.89
Face covering	0.01	0.34	0.14	0.02	1.24

Heritabilities

The heritabilities for the characters studied were estimated from the half-sib correlations as described by Lush (1949). It is assumed that the rams used were a random sample of Shropshire sires used in Wisconsin and that mating was random. Under this assumption σ_s^2, the sire variance and σ_e^2, the error variance, could be thought of as having been estimated from the same population. The heritability estimates can be approximated from the following formula:

$$h^2 = \frac{4\,\sigma_s^2}{\sigma_s^2 + \sigma_e^2}\,.$$

Using the variances presented in table 3 the heritabilities for body weight at 155 days, staple length at 239 days, and face covering at 247 days of age were .34, .49 and .61, respectively. Hazel and Terrill (1945b) found that heritability of weanling weight and staple length in range Rambouillet lambs were .30 and .40 respectively. The average heritability of weanling weight and staple length in the Columbia, Corriedale and Targhee sheep were .17 and .43, respectively (Hazel and Terrill, 1946b). Morley (1950)

TABLE 4. ESTIMATES OF COVARIANCE COMPONENTS

Characters	$\sigma_{aa'}$ Year	$\sigma_{ff'}$ Flock	$\sigma_{ss'}$ Sire	$\sigma_{tt'}$ Type of Birth	$\sigma_{ee'}$ Error
1 & 2	—0.16	0.10	—0.20	0.40	2.96
1 & 3	—0.05	—2.87	0.68	0.41	—2.95
2 & 3	—0.02	0.02	—0.13	0.00	—0.06

1=body wt. at 155 days.
2=staple length.
3=face covering.

reported estimates of .36 and .22 for these two heritabilities in Australian Merino sheep. Nelson and Venkatachalam (1949) reported a heritability of .33 for weanling weight of lambs under farm conditions. The heritability of staple length in the Romney sheep was .35 (Rae, 1950). Terrill and Hazel (1946) found heritability of face covering in range Rambouillet lambs to be .56.

Genetic correlations

Hazel (1943) and Hazel *et al.* (1943) described the methods of estimating genetic correlations. The formula used here is:

$$r_{G_iG_j} = \frac{4\sigma_{s_is_j}}{\sqrt{4\sigma^2_{s_i}\,4\sigma^2_{s_j}}}$$

$$= \frac{\sigma_{G_iG_j}}{\sigma_{G_i}\sigma_{G_j}}$$

The variances and covariances were taken from tables 3 and 4. The estimates obtained were $-.17$ for body weight with staple length, .57 for body weight with face covering, and $-.96$ for staple length with face covering. Correlations between the same characters were found to be $-.26$, $-.13$ and .08, respectively, in weanling Rambouillet lambs at the Western Sheep Breeding Laboratory (1946). The errors of estimate of genetic correlations are expected to be large. Those from the Western Sheep Breeding Laboratory were based on considerably larger numbers than those of this study and hence were more likely to reflect the true relationships.

The Index

Hazel (1943) outlined the principles followed in the development of the present indexes. The aggregate genic value of an individual was defined as

$$H = a_1G_1 + a_2G_2 + a_3G_3 + a_4G_4$$

where G_1, G_2, G_3 and G_4 are the genic values for body weight, staple length, face covering and grease fleece weight, respectively, and a_1, a_2, a_3 and a_4 are the relative economic values of these characters. The index which includes phenotypic measures of the characters available was defined by Henderson (1951) as:

$$I = a_1I_1 + a_2I_2 + a_3I_3 + a_4I_4$$

where:

$$I_1 = b_{11} x_1 + b_{12} x_2 + \ldots + b_{1n} x_n$$

.

.

.

$$I_4 = b_{41} x_1 + b_{42} x_2 + \ldots + b_{4n} x_n$$

then:

$$\begin{aligned} I &= a_1 (b_{11} x_1 + \ldots b_{1n} x_n) + \ldots \\ &\quad + a_4 (b_{41} x_1 + \ldots b_{4n} x_n) \\ &= (a_1 b_{11} + a_2 b_{21} + a_3 b_{31} + a_4 b_{41}) x_1 + \ldots \\ &\quad + (a_1 b_{1n} + a_2 b_{2n} + a_3 b_{3n} + a_4 b_{4n}) x_n \\ &= c_1 x_1 + \ldots c_n x_n \end{aligned}$$

I_1, I_2, I_3 and I_4 are indexes for estimating G_1, G_2, G_3 and G_4 utilizing information on the phenotypes of all characters, $x_1 \ldots x_n$, avail-

TABLE 5. PHENOTYPIC VARIANCES[1] AND COVARIANCES

Characters	Body Weight	Staple Length	Face Covering
Body weight	*94.67*	1.16	−1.37
Staple length		*.73*	.00
Face covering			*1.18*

[1] The variances are the figures in italics.

able at the time of selection. The b's are regression coefficients maximizing the correlation between I_i and G_i which will automatically maximize the correlation between H and I. The cj's are regression coefficients obtained by collecting the appropriate ($a_i b_{ij}$) terms or by using the same method used to calculate the b's and shown to maximize r_{HI}. One reason for calculating the I_i's as intermediate steps is that, when selection is for one character at a time, the effect of each character on each other one is more readily apparent. Another reason is that the relative economic values do not enter into the calculations until the last step, thereby making it easier to substitute different economic values without recalculating the other parts of the equations if the rest of the statistics are still appropriate.

Table 5 presents the phenotypic variances and covariances used in the index. The variances are those given in table 2 and the

covariances were calculated from the relationship $\sigma_{x_i x_j} = r_{x_i x_j} \sigma_{x_i} \sigma_{x_j}$. The phenotypic correlation between staple length and face covering was considered zero because of the low values obtained in this study (−.02) and the Western Sheep Breeding Laboratory (+.02).

The genetic variances and covariances used are presented in table 6. The genetic variances for body weight, staple length and face covering were estimated from the relationship $\sigma_G^2 = h^2 \sigma_x^2$ where h^2 is the heritability estimate given earlier. The large errors of estimate expected to be associated with the genetic correlations in the present study made it appear unwise to use them. The genetic variance for fleece weight and the covariances in table 6 were obtained from data

TABLE 6. GENETIC VARIANCES[1] AND COVARIANCES

Characters	Body weight	Staple length	Face covering	Grease fleece weight
Body weight	*32.19*[2]	−.35[3]	−.28[3]	.17[4]
Staple length		*.36*[2]	.01[3]	.10[5]
Face covering			*.72*[2]	.00[6]
Grease fleece wt.				*.17*[5]

[1] Variances are in italics.
[2] Calculated from our data.
[3] Western Sheep Breeding Laboratory report (1946).
[4] Morley (1950).
[5] Rae (1950).
[6] Terrill (1949).

presented by the Western Sheep Breeding Laboratory (1946), Morley (1950) and Rae (1950). The genetic covariance between fleece weight and face covering was considered to be zero on the basis of a small and insignificant phenotypic correlation between yearling grease fleece weight and weanling face covering score as reported by Terrill *et al.* (1950) and a study made by Terrill (1949) in which he found the phenotypic differences between open-faced and closed-faced ewes in fleece weight to be small and insignificant.

The following four indexes were calculated and correlations between each of them and H were compared. The same H value, aggregate genic value, was used in the correlations with each of the four indexes.

(1) Includes body weight (x_1), staple length (x_2) and face covering (x_3).

$$I_1 = a_1 I_{11} + a_2 I_{21} + a_3 I_{31} + a_4 I_{41}$$
$$I_{11} = .355\ x_1 - 1.044\ x_2 + .175\ x_3$$
$$I_{21} = -.003\ x_1 + .497\ x_2 - .003\ x_3$$
$$I_{31} = .006\ x_1 + .004\ x_2 + .617\ x_3$$
$$I_{41} = .000\ x_1 + .137\ x_2 + .000\ x_3$$
$$= .346\ x_1 - .502\ x_2 - .751\ x_3$$
$$\text{or } I_1 = x_1 - 1.5\ x_2 - 2.2\ x_3$$
$$r_{I_1 H} = .581$$

(2) Includes body weight (x_1) and face covering (x_3)

$$I_2 = x_1 - 2.1\ x_3$$
$$r_{I_2 H} = .577$$

(3) Includes body weight (x_1) and staple length (x_2)

$$I_3 = x_1 - 1.4\ x_2$$
$$r_{I_3 H} = .565$$

(4) Body weight alone

$$I_4 = x_1$$
$$r_{I_4 H} = .563$$

The x's are in terms of deviations from the means. x_3 appears with a negative sign in I_1 and I_2 indicating that, other things being equal, open faced lambs will have higher index values than closed-faced lambs.

Discussion

Genetic improvement of sheep in economically important characters may involve many aspects of lamb and wool production. Lamb production may be made more profitable by increasing the number of lambs per ewe reaching market weight each year, by producing faster growing lambs that gain more per unit of feed intake, by improving market grade, by increasing dressing percentage and by producing carcasses of better grade. Returns from wool production may be increased by adding to the pounds of wool per fleece, by increasing the length of staple and by producing wool of better grade in terms of average fineness, uniformity in fineness per fleece and absence of defective fibers. Some breeders would be interested in improving their sheep in all these characters but the opportunity, the need, and the desire for change in each of these characters will vary from breeder to breeder because of their personal preferences, the level of the characters in their flock, the amount of variability present, the selection intensity allowed by the replacements needed and the differences in farm practice due to kind or

location of farm. Likewise, the goal of the breeder may change from time to time according to market demands or as new and better management practices become available. Any of these factors could play an important role in determining the characters to consider in a selection program and the relative emphasis to place on those included.

A complete selection index would include all heritable characters which are considered of economic importance and are available on the individuals or their relatives at the time of selection. The differences that exist in the emphasis which ought to be placed on certain characters from flock to flock and from time to time and the uncertainties as to the precise values of some of the economic and biological statistics needed in deciding on the relative importance of some of these characters leads to the development of an index which is obviously not completely accurate for each set of conditions. A single index of general farm use is, however, a useful device for reflecting the major economic and heritable differences between animals within a flock. As more precise statistical information becomes available for different breeds and for specific circumstances, modifications in the index will undoubtedly be called for. Clearly, such things as lethals, abnormalities or other undesirable traits will also need to be considered as the occasion arises within particular flocks.

Comparison of the correlation between each of the four indexes developed in this study and the aggregate genic value shows that the first index, including body weight, staple length and face covering, should provide the greatest gain. However, staple length appears to contribute little to the precision of predicting the aggregate genic value of an individual and is, of course, time consuming to measure. Hence the second index, equal to body weight minus twice face covering score (scale from 1 to 7 with 1 = open face and 7 = closed face) is indicated by this study to be of equivalent practical value. In many flocks this will resolve itself into selecting on weight for age only and in most flocks weight for age would be the determining factor, with face score playing only a minor role in selection. The reason for this is the relatively small variability within flocks in face covering compared with body weight. It is fortunate that this is so because of the subjective basis for face covering classification and highly arbitrary nature of the decision as to the relative economic value of the different classes of face covering used in this study.

The data for body weight were taken at 155 days and for face covering at 247 days of age. Regression of body weight at 247 days on

weight at 155 days was .97 as calculated within year, flock, sire and type of birth, from data available on the lambs of this study. Regressions of 1.08 and .90 for weight at 9 months on weight at 6 months in Merino rams and ewes, respectively, were obtained from data presented by Morley (1950). On the basis of these regressions ($\cong$1.00) it would be expected that the differences between individuals would be quite similar whatever age they were measured between weaning and eight or nine months of age. For actual use in the field weanling age would be preferable to allow selection to be based on the index prior to the time lambs reach market weight.

The indexes reported here are for use only within year and flock since the statistics used were calculated within such classifications and no adjustments are available for differences between years and between flocks. It should be pointed out that it was necessary to make certain arbitrary decisions in regard to classification of face covering, economic value of staple length, etc. and until further data are analyzed the basis for these decisions must be borne in mind. Likewise no estimates of non-additive genetic variance were available; hence, it may be necessary to modify the selection procedures as well as the mating plans in the light of later knowledge on the importance of non-additive genetic variability.

The data which are now being collected in cooperation with sheep breeders in Wisconsin are directed toward solving some of these problems. Records are now becoming available on number of lambs weaned per ewe, grease fleece weight, mature weight of the ewes and market grade of the lambs. Additional data are also being collected on body weight, staple length and face covering of the lambs at an age close to market time. These data should provide more precise estimates of the parameters necessary for improving the present index.

Summary

Four indexes for selecting lambs of Shropshire breeding were developed. These contain one or more of the three characters studied—body weight, staple length and face covering. Each of the indexes was directed toward selecting for the same aggregate genotype containing the genic values of these three characters as well as grease fleece weight. The genic values of these four characters were weighted by their respective relative economic values *per se* and in relation to other characters which contribute to profit in the sheep enterprise.

The index equivalent to body weight of the lamb at weaning minus

twice face covering score is the one suggested as the most practical for farm use. Face covering is scored on a scale from one to seven with one equal to open face and seven closed face.

Estimates of economic values, phenotypic and genetic correlations and heritabilities are given.

Literature Cited

Agricultural Statistics (1936–1950). U.S.D.A.

Bonsma, F. N. 1939. Factors influencing the growth and development of lambs with special reference to cross-breeding of Merino sheep for fat lamb production in South Africa. U. of Pretoria Publications, Series 1: Agriculture No. 48, 214 pp., illus.

Brody, S. 1945. Bioenergetics and growth. Reinhold Publishing Co.

Donald, H. P. and J. W. McLean. 1935. The growth rate of lambs in Canterbury. A preliminary study of the variation in the growth rate of lambs in Canterbury. New Zealand Jour. Sci. and Tech. 17:497.

Hazel, L. N. 1943. The genetic basis for constructing selection indexes. Genetics 28:476.

Hazel, L. N., Marvel L. Baker and C. F. Reinmiller. 1943. Genetic and environmental correlations between the growth rates of pigs at different ages. JOURNAL OF ANIMAL SCIENCE 2:118.

Hazel, L. N. and J. L. Lush. 1942. The efficiency of three methods of selection. Jour. Heredity 33:393.

Hazel, L. N. and C. E. Terrill. 1945a. Effects of some environmental factors on weanling traits of range Rambouillet lambs. JOURNAL OF ANIMAL SCIENCE 4:331.

Hazel, L. N. and C. E. Terrill. 1945b. Heritability of weaning weight and staple length in range Rambouillet lambs. JOURNAL OF ANIMAL SCIENCE 4:347.

Hazel, L. N. and C. E. Terrill. 1946a. Effects of some environmental factors on weanling traits of range Columbia, Corriedale and Targhee lambs. JOURNAL OF ANIMAL SCIENCE 5:318.

Hazel, L. N. and C. E. Terrill. 1946b. Heritability of weanling traits in range Columbia, Corriedale and Targhee lambs. JOURNAL OF ANIMAL SCIENCE 5:371.

Hazel, L. N. and C. E. Terrill. 1946c. Effects of some environmental factors on fleece and body characteristics of range Rambouillet yearling ewes. JOURNAL OF ANIMAL SCIENCE 5:382.

Henderson, C. R. 1948. Estimation of general, specific and maternal combining abilities in crosses among inbred lines of swine. Unpublished Ph.D. Thesis, Ames, Iowa, Iowa State College Library.

Henderson, C. R. 1951. Cornell University, Ithaca, New York (Mimeographed).

Henderson, C. R. 1952. Estimation of variance and covariance components. North Carolina Summer Statistics Conference. June 24, 1952 (Mimeographed).

Krause, O. E. 1950. Wisconsin sheep production and marketing. Wis. State Dept. of Agr. Bull. No. 301.

Lush, J. L. 1949. Heritability of quantitative characters in farm animals. 8th International Congress Genetics Proc. (Hereditas Suppl. Vol.) 356–375.

Morley, F. H. W. 1950. Selection for economic characters in Merino sheep. Unpublished Ph.D. Thesis, Ames, Iowa, Iowa State College Library.

National Research Council. 1945. Recommended nutrient allowances for sheep.

Nelson, R. H. and G. Venkatachalam. 1949. Estimates of heritability of birth weight and weaning weight of lambs. JOURNAL OF ANIMAL SCIENCE 8:607. (Abs.)

Phillips, Ralph W. and G. W. Brier. 1940. Estimating weights of lambs at a constant age. U.S.D.A. Cir. No. 541. 16 pp.

Phillips, Ralph W. and W. M. Dawson. 1940. Some factors affecting survival, growth and selection of lambs. U.S.D.A. Cir. No. 538. 18 pp.

Phillips, Ralph W., J. A. Stoehr and G. W. Brier. 1940. Growth in the Corriedale and Rambouillet sheep under range conditions. Amer. Soc. Anim. Prod. Proc. 173–181.

Rae, A. L. 1950. Genetic variation and covariation in productive characters of New Zealand Romney Marsh sheep. Unpublished Ph.D. Thesis, Ames, Iowa, Iowa State College Library.

Smith, H. Fairfield. 1936. A discriminant function for plant selection. Ann. Eugen. 7:240.

Terrill, Clair E. 1941. Face covering in range sheep. U.S.D.A., A.H.D. No. 49, 9 pp.

Terrill, Clair E. 1949. The relation of face covering to lamb and wool production in range Rambouillet ewes. JOURNAL OF ANIMAL SCIENCE 8:353.

Terrill, C. E. and L. N. Hazel. 1946. Heritability of face covering and neck folds in range Rambouillet lambs as evaluated by scoring. JOURNAL OF ANIMAL SCIENCE 5:170.

Terrill, C. E., W. H. Kyle and L. N. Hazel. 1950. Correlations between traits of range Rambouillet rams. JOURNAL OF ANIMAL SCIENCE 9:540. (Abs.)

Terrill, C. E., G. M. Sidwell and L. N. Hazel. 1947. Effects of some environmental factors on yearling traits of Columbia and Targhee ewes. JOURNAL OF ANIMAL SCIENCE 6:115.

Terrill, C. E., G. M. Sidwell and L. N. Hazel. 1948a. Effects of some environmental factors on yearling traits of Columbia and Targhee rams. JOURNAL OF ANIMAL SCIENCE 7:181.

Terrill, C. E., G. M. Sidwell and L. N. Hazel. 1948b. Effects of some environmental factors on traits of yearling and mature Rambouillet rams. JOURNAL OF ANIMAL SCIENCE 7:311.

Western Sheep Breeding Laboratory. 1946. 9th Annual Report, Dubois, Idaho.

Wisconsin Crop and Livestock Reporter. 1936–1951. Wisconsin Dept. of Agric.

A RAPID METHOD FOR THE ESTIMATION OF CLEAN FLEECE WEIGHT WITH THE AID OF A NEW WOOL DENSITY DEVICE[1]

KHALID T. ALI, P. E. NEALE and WM. D. MCFADDEN[2]

New Mexico Agricultural Experiment Station

THE amount of clean wool produced by the individual sheep greatly influences the financial return from wool production, and indeed, from the range sheep enterprise.

Clean fleece weight, presumably, is a function of body weight (in so far as the weight is correlated with body surface), fineness, length and density, assuming that variation in the specific gravity is not important. Within grades there seems to be no question regarding the desirability of increased length and density resulting from selection for clean fleece weight. The accompanying increase in body weight, however, raises the question of the efficiency of production, i.e., the amount of wool and lamb produced per unit of body weight.

Various workers, dealing with range and farm sheep, agree that within breeds the body weight is associated with the amount of wool and lamb produced, (Joseph 1931, Hunt 1935, Terrill and Stoehr 1942, and Ali 1951). Hunt (1935), however, reported that production of lamb and wool per 100 pounds of ewe decreased as the size of the ewe increased. Terrill and Stoehr (1942) found that larger Rambouillet and Corriedale ewes were more efficient producers of lamb than the smaller ewes, whereas the situation was reversed in the Columbia ewes. The efficiency of wool production, however, was negatively associated with body weight in all the three breeds. Terrill and Stoehr say, "It is believed that with range sheep the cost of operation is more related to the number of sheep than to the feed requirements of individual sheep and if this is true the larger sheep would, in general, be more profitable provided there was sufficient range feed available."

The present work is an attempt to develop equations for the prediction of clean fleece weight (CFW) of range Rambouillet rams from the body weight (BW), staple length (SL), and density of wool (D) as measured by a new device described below. The relationships of

[1] Journal Series No. 75, New Mexico Agricultural Experiment Station, State College, New Mexico.

[2] Agricultural Specialist, Dept. of Agriculture, Baghdad, Iraq; Animal Husbandman, New Mexico Agricultural Experiment Station; and Assistant in Agricultural Economics, New Mexico Agricultural Experiment Station, respectively.

grease fleece weight (GFW) to other variables was also investigated for possible use in the prediction whenever GFW is available. The method is designed for rapid application in the field by the sheep breeder. The predicted clean fleece weight should serve as a guide in the selection of breeding animals as well as in estimating shrinkage.

The relationships between some or all of the five variables under consideration have been investigated by Spencer *et al.* (1928), Pohle and Keller (1943), Terrill *et al.* (1945), Terrill *et al.* (1950), and Ali (1951).

With few exceptions the correlation coefficients (r) between any given two variables found by the various workers are fairly consistent. The range in the coefficients between CFW and BW was .3 to .4 and that between GFW and BW was from .3 to .5. Whenever the above two r's were obtained in one investigation, that between GFW and BW was almost always larger than the other. The r between CFW and SL was from .4 to .6 and that between GFW and SL, from .2 to .4. Whenever the last two r's were obtained in one investigation that between CFW and SL was invariably larger than the other.

Only Spencer *et al.* (1928) correlated D with either CFW or GFW. They found that the r between D and GFW (.24) was larger than that between D and CFW (.17). To measure D, these workers felt the fleeces by hand. Since fleeces higher in their grease content feel denser when touched by hand, the correlations found are probably biased.

The r's between GFW and CFW reported in the studies fall between .6 and .7. In each investigation in which this correlation was obtained together with others it was found to be higher than the correlation between any other two of the five variables under consideration.

The r between BW and SL appears to be insignificant but in the negative direction (−.08 to −.16). Spencer *et al.* (1928) found small but positive r's between BW and D and between SL and D.

Most of the literature on wool density, which is defined as the number of fibers per unit of body surface, deals with the following three aspects of the problem:

(1) Devices (calipers) for obtaining wool samples from defined areas (Burns 1925, Nordby 1928, Duerden 1929, Burns and Miller 1931, Hardy 1932, Wildman 1936, and Hardy 1942).

(2) Instruments, techniques and methods for determining the actual density in the laboratory from the samples obtained (Burns and Miller 1931, Bosman 1934, Carter 1939, and Hardy and Wolf 1942).

(3) Studies on the accuracies and practicabilities of the density methods (Burns 1937, Madsen *et al.* 1941, and Wolf *et al.* 1943).

Some overlapping of the three aspects of the problem exists in the literature cited above.

All the methods referred to above are time consuming and require laboratory equipment and training which are beyond the reach of the average wool grower. From the practical point of view density is an important index of the amount of clean wool produced by the individual

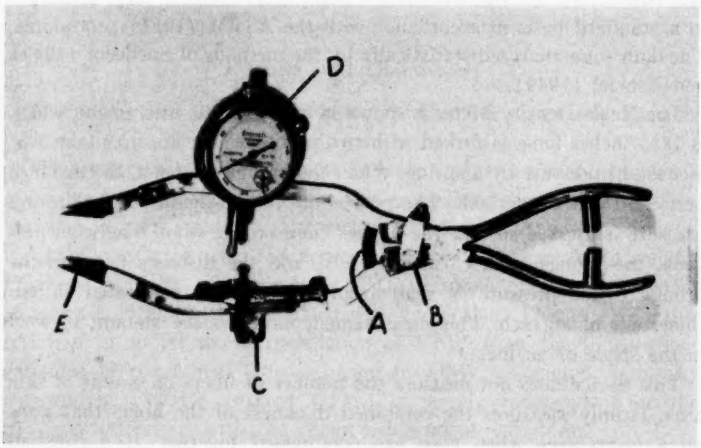


Figure 1. The Neale Density Meter. a—constant pressure spring. b—stop to control size of fork opening. c—stop to prevent backlash and maintain constant pressure. d—dial for recording width between points (e) when pressure is applied. e—prongs of the fork which are placed against skin when measuring (released width 1").

sheep. If devices measuring the "relative density" are simple, inexpensive and rapid they should prove to be quite useful to the sheep grower as a guide in selecting his breeding animals. The "Neale Density Meter" has been devised by one of the authors to fulfill these requirements. This paper describes the instrument and reports results from tests with it.

Materials and Methods

The data were obtained on 167 fine wool range Rambouillet rams, all raised on the same ranch under the same general conditions. All the data were obtained in the same year and season.

Before the rams were sheared, they were weighed individually and the weights were recorded to the nearest pound. The relative density was then obtained on the hip. This was done by opening the fleece on the hip with one hand and applying the Neale Density Meter with the other hand. A lock sample was then taken from about the same place on the hip for unstretched staple length measurement which was expressed in sixteenths of an inch. The fleeces were then shorn, weighed, and sent for scouring whole to the wool laboratory of the Agricultural and Mechanical College of Texas. Clean fleece weights were corrected to a standard basis in accordance with the ASTM (1951) procedures. The data were analyzed statistically by the methods of Snedecor (1948) and Ezekiel (1949).

The Neale Density Meter is shown in figure 1. The instrument, which is 12½ inches long, is forked with two prongs which are maintained at a constant pressure by a spring. When the prongs are open, the distance between them is one inch. The prongs are placed against the skin and pressure is applied so that the prongs close on the wool. The wool prevents the prongs from closing entirely, and the distance between the prongs under pressure is read from a dial scale calibrated in ten thousands of an inch. This measurement indicates the amount of wool in the space of an inch.

This device does not measure the number of fibers on a unit of skin area. It only measures the combined thickness of the fibers that grow on a given area when they are compressed together at a constant pressure.

McFadden and Neale (1952) tested the reliability of the Neale Density Meter. The following are some of the results they obtained: (1) There was no significant differences between several readings taken consecutively on the same position (hip) of the same sheep by the same operator. (2) Because some bias might have entered when the readings were taken consecutively, a time lapse was introduced. Two readings were taken on a group of sheep on two different days. No significant differences were found between readings. (3) Two operators measured the same individuals on the same position (hip). Significant differences were found to exist between the readings of the two operators. However, the correlation coefficient between the readings of each operator was found to be highly significant (.58) indicating that the relative density was measured fairly accurately by either operator. (4) Most of the variation was found to exist between sheep.

TABLE 1. MEANS AND STANDARD DEVIATIONS

Rams	Number	BW (lbs.) Mean	BW (lbs.) S.D.	SL (inches) Mean	SL (inches) S.D.	D (arbitrary) Mean	D (arbitrary) S.D.	GFW (lbs.) Mean	GFW (lbs.) S.D.	CFW (lbs.) Mean	CFW (lbs.) S.D.
Yearling	110	117	11.0	3.34	.34	24	2.5	11.6	1.5	4.8	.57
Mature	57	156	15.2	3.34	.36	22	3.0	15.4	1.8	6.3	.82
Total	167	130	12.6	3.34	.35	23	2.7	12.9	1.6	5.3	.66

BW=Body weight.
SL=Staple length.
D=Density of wool.
GFW=Grease fleece weight.
CFW=Clean fleece weight.

Results and Discussion

The means and standard deviations of the five traits are shown in table 1.

The gross correlation coefficients between each two variables for each of the age groups and for within age groups are shown in table 2.

It can be seen (table 2) that each of the four independent variables is highly correlated with the dependent variable—clean fleece weight. Furthermore, with the exception of GFW, none of the independent variables is significantly correlated with each other. This is a desirable situation in so far as the prediction of CFW from the independent variables is concerned. The variance in CFW associated with any independent variable (except GFW) is largely independent of the fractions associated with the other independent variables.

TABLE 2. THE CORRELATION COEFFICIENTS

		SL	D	GFW	CFW
BW	Yearling	.03	.01	.32**	.39**
	Mature	—.13	.14	.46**	.41**
	Within age groups	—.04	.07	.38**	.40**
SL	Yearling		—.10	.40**	.55**
	Mature		.07	.23	.38**
	Within age groups		—.03	.33**	.47**
D	Yearling			.10	.18
	Mature			.19	.48**
	Within age groups			.14	.32**
GFW	Yearling				.70**
	Mature				.55**
	Within age groups				.63**

** Highly significant.

Within age groups, BW, SL and D are more highly correlated with CFW than with GFW. This is most noticeable with D, which is only insignificantly correlated with GFW but highly correlated with CFW. The higher correlation with CFW holds true in each of the two age groups with one exception (BW correlation with CFW and GFW in the mature group). Within age groups GFW is most highly correlated with CFW followed by SL, BW and D in this order.

The main features of these correlations seem to agree well with the findings of Terrill *et al.* (1945), Terrill *et al.* (1950), Pohle and Keller (1943), and Ali (1950). Considering the effect of sampling errors, of

TABLE 3. THE PREDICTION EQUATIONS

Equation Number	Age group	Variable deleted	σ	Partial regression coefficients of CFW on: BW (lbs.)	SL (1/16 inch)	D (arbitrary)	GFW (lbs.)
1	Yearling	None	−1.53	.012±.003	.039±.007	.039±.013	.172±.026
1A	Mature		−2.66	.014±.006	.045±.014	.101±.025	.134±.051
2	Yearling	GFW	−1.72	.019±.004	.058±.007	.053±.016	
2A	Mature		−2.57	.022±.005	.057±.014	.109±.027	
3	Yearling	GFW + D	− .35	.019±.004	.055±.007		
3A	Mature		− .89	.025±.006	.062±.016		
4	Yearling	GFW+ D+ SL	2.51	.020±.005			
4A	Mature		2.86	.022±.007			

the method of analysis used, and of the nature of these relationships in various materials, greater degree of similarity should hardly be expected.

The multiple regression prediction equations are shown in table 3.

As seen from table 3 the prediction equations were calculated for each age group. This should give more accurate estimates than if the within age groups' regressions were used. If measurements on all the four independent variables are available, equation 1 should be used with yearling rams and 1A with mature rams. Thus the predicted CFW of a yearling ram whose body weight is 123 pounds, staple length is 56/16 inch (3.5 inches), density is 26 units and grease fleece weight is 12 pounds, equals: $CFW = -1.53 + (.012)(123) + (.039)(56) + (.039)(26) + (.172)(12.0) = 5.2$ pounds. If grease fleece weight is unknown, equation 2 or 2A must be used, depending on the age of the ram.

Since the purpose of the present work is the prediction of clean

fleece weight from body weight, staple length and density, equations 2 and 2A are of the major importance for this purpose. In addition to the possibility of their use in prediction, the other equations were made and analyzed for accuracy to demonstrate the effect of each of the independent variables on the accuracy of prediction.

Although the partial regression coefficients are required in the prediction equations, the standard partial regression coefficients are more informative for comparing the regression of CFW on each of the

TABLE 4. THE STANDARD PARTIAL REGRESSION COEFFICIENTS

Line	Age Group	Variable deleted	Standard partial regression coefficients of CFW on: BW	SL	D	GFW
1	Yearling	None	.228	.377	.170	.458
1A	Mature		.265	.320	.369	.290
2	Yearling	GFW	.367	.564	.232	
2A	Mature		.406	.403	.399	
3	Yearling	GFW + D	.371	.540		
3A	Mature		.465	.438		
4	Yearling	GFW+ D+ SL	.388			
4A	Mature		.408			

independent variables when the others were kept constant. The standard partial regression coefficients are shown in table 4.

Although BW, SL, and D were kept constant (table 4, line 1) the standard partial regression of CFW on GFW is still large (.458). This indicates that even if the other three variables are not changing, a change in GFW is still associated with significant change in CFW (for the test of the significance of the standard partial regressions see table 3). Such a result could be accounted for if there were some errors in the measurement of BW, SL and D.

The order of magnitude of the coefficients in line 1 is a little different than in line 2, also between lines 1A and 2A. This can be explained from the correlation coefficients of table 2. The change in magnitude in the coefficients of 2 and 2A lines as compared to the corresponding ones in lines 1 and 1A resulted from allowing variation in GFW, which is correlated with the other independent variables (table 2). Since

such relationships are insignificant between D and BW, and D and SL, almost no change took place in the coefficients of lines 3 and 3A as compared to 2 and 2A. Other changes may be explained in the same manner.

The accuracy of prediction, using the different equations (table 3) is shown in table 5 for each case.

The relative importance of each independent variable in predicting CFW can be seen clearly from the information in table 5. Consider,

TABLE 5. THE ACCURACY OF PREDICTION OF CLEAN FLEECE WEIGHT

Age Group	Variable deleted	Variance of estimate	Standard error of estimate	Coefficient of determination R^2	Coefficient of multiple correlation R
Yearling	None	.117	.342	.648	.805
Mature		.313	.560	.567	.753
Yearling	GFW	.166	.407	.495	.704
Mature		.348	.590	.509	.714
Yearling	GFW + D	.182	.426	.442	.665
Mature		.450	.670	.355	.595
Yearling	GFW+ D+ SL	.274	.524	.150	.388
Mature		.570	.755	.166	.408
Yearling	All	.320	.566		
Mature		.672	.820		

for example, the mature group. If no criterion is used to predict the CFW of an individual in this group the best estimate would be the mean of the group, 6.3 pounds with a standard deviation of .82 pounds. When body weight alone is used in the prediction the error of estimate is .76 pounds instead of .82, and so forth. The other three columns of table 5 provide other measures of the importance of each of the independent variables but in different terms.

Table 6 compares the importance of each variable when the differences between the standard errors of estimate are used as a measure.

Table 6 indicates that staple length was the most important in each case. Body weight occupied the third place in both groups, whereas density and grease fleece weight occupied opposite positions in the two

groups, density being more important in the mature group. This shows that although grease fleece weight was more highly correlated with clean fleece weight than any of the other variables, the variation in clean fleece weight due to grease fleece weight independent of the other variables is considerably smaller than appears from the gross correlation.

It appears that the method of prediction used is quite practical and accurate. Without interfering with the practicability of the method, greater accuracy of prediction may be obtained upon the study of the following possibilities: (1) More than one area of the fleece is sampled for density and staple length measurements to determine if any one of them or their average is more representative of the whole fleece. (2) The density device used appears to measure the linear differences in

TABLE 6. REDUCTION IN STANDARD ERROR OF ESTIMATE (POUNDS) DUE TO EACH INDEPENDENT VARIABLE AND THE ORDER OF THEIR IMPORTANCE

	Yearling		Mature	
Independent Variable	Reduction in S. D.	Order of Importance	Reduction in S.D.	Order of Importance
Body weight	.042	3	.065	3
Staple length	.098	1	.085	1
Density	.019	4	.080	2
Grease fleece weight	.065	2	.030	4

density. The square of the reading might be more highly correlated with clean fleece weight. (3) An estimate of the body surface to be used instead of the body weight may show higher correlation with clean fleece weight than body weight with clean fleece weight. Measurements of body length, width and depth will probably provide a satisfactory measurement of the body surface. (4) Analyses similar to the present one should be conducted on various breeds, strains, sexes and ages, and in various localities and years to determine the most accurate prediction equation for a given set of conditions. (5) The linearity of the relationship between the variables in question should be tested.

This study was made with Rambouillet sheep and the results apply to this breed, but they may have adaptations to other breeds and types.

Work is under way investigating the above mentioned possibilities.

Summary

A new device for the measurement of the relative density called the Neale Density Meter was described.

Regression equations were constructed for the prediction of the clean fleece weight (CFW) of range yearling and mature fine wool Rambouillet rams. Body weight (BW), staple length (SL) and density (D) were used in the prediction equations. There were available 110 yearling and 57 mature rams for this analysis. The prediction method was designed to be rapid so that selection on the basis of CFW may be made directly in the field. Grease fleece weight (GFW) also entered the analysis to investigate its relationships to the other variables and to be used in the prediction whenever it was available. The following highly significant correlations between CFW and the other variables were obtained (within age groups): BW=.40, SL=.41, D=.32, and GFW=.63. The correlation of GFW with each of the other variables was smaller in each case than the correlation of that variable with CFW. There was no significant correlation between any two of the three variables: BW, SL and D. The multiple correlation coefficient (R) of CFW with BW, SL, D and GFW was .81 for the yearlings and .75 for the matures. When GFW was eliminated the corresponding R's were .70 and .71, respectively.

Measured in terms of the net variation in CFW associated with each of the other variables, their order of importance in prediction is: yearling—1st SL, 2nd GFW, 3rd BW, 4th D; mature 1st SL, 2nd D, 3rd BW and 4th GFW.

In the case of yearlings the standard deviation of CFW was .57 pounds. When BW alone was used in prediction the S.E. of estimate became .52, when SL was added it became .43, and when D was added it became .41, and when GFW was added it became .34 pounds. The corresponding figures for the mature group are: .82, .76, .67, .59 and .56.

It was concluded that the method of prediction should prove useful in selecting breeding animals. Certain suggestions thought to further increase the accuracy of prediction, without interfering with the practicability of the method, were made.

Literature Cited

Ali, Khalid T. 1951. The heritability of, and the effects of some environmental factors on the birth weight, the weaning weight and the grease fleece weight of sheep. Ph.D. thesis, U. of Minnesota, Minneapolis, Minnesota.

American Society for Testing Materials, ASTM Standards on Textile Materials (with related information), October 1951, Philadelphia, Designation D 584–50, pp. 435.

Bosman. V. 1934. The determination of fleece density in the Merino sheep. Onderstepoort Journal of Veterinary Science and Animal Industry 3:217.

Burns, R. H. 1937. Fleece density of sheep. The Wyedesa Fleece Caliper. The Journal of the Textile Institute 28:113.

Burns, R. H. and W. C. Miller. 1931. Sampling instruments to determine fleece density in sheep. The Journal of the Textile Institute 22:547.

Burns, R. H. 1925. Some phases of wool inheritance in the F_1 generation. American Society of Animal Production, Proceedings, 1924:92. Cited in Burns and Miller, 1931.

Carter, H. B. 1939. A histological technique for the estimation of follicle population per unit area of skin in the sheep. Journal of the Council for Scientific and Industrial Research (Australia) 12:250.

Duerden, J. E. 1929. Wool Research in South Africa. Union of South Africa. Dept. of Agriculture. Pan-African Agricultural and Veterinary conference, Pretoria, 1st Aug.-17th Aug. 1929. Papers—Agricultural Section, pp. 344. Cited in Burns and Miller, 1931.

Ezekiel, M. 1949. Methods of Correlation Analysis. John Wiley and Sons, Inc., New York.

Hardy, J. I. and H. W. Wolf. 1942. Cross-Section-Area method for determining density of wool fibers. U.S.D.A. Circular 654.

Hardy, J. I. 1942. A clipper for obtaining wool density samples. JOURNAL OF ANIMAL SCIENCE 1:34.

Hardy, J. I. 1932. A simple method of determining clean-wool yield and density of fleeces. American Society of Animal Production. Proceedings, 234.

Hunt, W. E. 1935. The effect of size and type of ewe on efficiency of production. Maryland Agricultural Experiment Station Bulletin 380.

Joseph, W. E. 1931. Relation of size of grade fine wool ewes to their production. Montana Agricultural Experiment Station Bulletin 242.

Madsen, M. A., R. W. Phillips, J. V. Christensen, and R. L. Henrie. 1941. Comparison of two methods of determining wool density. Utah Agricultural Experiment Station Technical Bulletin 295.

McFadden, Wm. D. and P. E. Neale. 1952. Unpublished report. New Mexico Agricultural Experiment Station, State College, New Mexico.

Nordby, J. E. 1928. The Idaho Wool Caliper and its application in making density determinations. Idaho Agricultural Experiment Station Circular 52.

Pohle, E. M., and H. R. Keller. 1943. Staple length in relation to wool production. JOURNAL OF ANIMAL SCIENCE 2:33.

Snedecor, G. W. 1948. Statistical Methods Applied to Experiments in Agriculture and Biology. The Iowa State College Press, Ames.

Spencer, D. A., J. I. Hardy, and M. J. Brandon. 1928. Factors that influence wool production with range Rambouillet sheep. U.S.D.A. Technical Bulletin 85.

Terrill, C. E., W. H. Kyle and L. N. Hazel. 1950. Correlations between traits of range Rambouillet rams. Mimeographed paper presented at the meetings of the American Society of Animal Production at Chicago, Illinois.

Terrill, C. E., E. M. Pohle, L. O. Emik and L. N. Hazel. 1945. Estimation of clean-fleece weight from grease-fleece weight and staple length. Journal of Agricultural Research 70:1.

Terrill, C. E. and J. A. Stoehr. 1942. The importance of body weight in selection of range ewes. JOURNAL OF ANIMAL SCIENCE 1:221.

Wildman, A. B. 1936. An improved fleece-sampling instrument. The Journal of the Textile Institute 27:177.

Wolf, H. W., W. M. Dawson, and E. M. Pohle. 1943. Fiber density and some methods of its measurement in fleeces of Rambouillet sheep. JOURNAL OF ANIMAL SCIENCE 2:188.

THE EFFECTS OF HORMONES ON THE GROWTH AND FATTENING OF LAMBS[1]

T. M. MEANS, F. N. ANDREWS and W. M. BEESON[2]

Purdue University Agricultural Experiment Station

DURING the past decade it has become increasingly clear that growth rate, the efficiency of feed utilization and the chemical composition of meat animals can be altered by hormone administration. The snythesis of naturally occurring hormones and other compounds with hormonal activity has made it economically feasible to consider the practical applications of endocrinology to meat animal production.

In wether lambs the subcutaneous implantations of compressed stilbestrol pellets has consistently improved rate of gain and increased the efficiency of feed utilization (Andrews *et al.*, 1949 and 1952; Jordan, 1950; O'Mary *et al.*, 1951; Pope *et al.*, 1950). Similar results have been obtained with ewe lambs (O'Mary *et al.*, 1951). Perry *et al.*, 1951, reported increased rates of gain in stilbestrol-treated suckling lambs, although Jordan and Dinusson (1950) were unable to stimulate gain in suckling lambs with stilbestrol. In general, the above mentioned studies have shown a reduction in carcass quality as measured by official Federal carcass grades, when stilbestrol has been used.

The purpose of these experiments was to gather more information on the effects of stilbestrol on growth rate, feed efficiency and carcass quality and to compare compressed stilbestrol pellets with testosterone pellets and with dienestrol administered in two different injectable bases.

Materials and Methods

Two experiments were conducted, the first between January 2, 1950 and March 16, 1950, and the second from November 7, 1950 to February 7, 1951. In the first experiment 10 lots of 10 lambs (Hampshire X western ewes) averaging 74 lbs. each were used. In the second experiment 10 lots of similar type lambs averaging 81 lbs. each were used. Two lots of 10 lambs each were assigned to each treatment. In the first experiment the treatments were as follows: Group I, controls;

[1] Contribution from the Department of Animal Husbandry, Journal Paper No. 634, Purdue University, Agricultural Experiment Station, Lafayette, Indiana.

[2] The authors express their appreciation to Wick and Fry, Inc., for the stilbestrol, to the Ortho Research Foundation for the dienestrol and to the Ciba Pharmaceutical Products, Inc., for the testosterone used in these experiments.

Group II, one 12 mg. stilbestrol pellet; Group III, two 12 mg. stilbestrol pellets; Group IV, 12 mg. of dienestrol in 1 cc. of a base of high viscosity (Type A); Group V, two 15 mg. pellets of testosterone. In the second experiment groups I, II, III and V were identical with the above. Group IV was treated with 12 mg. of dienestrol in 1 cc. of a base of low viscosity (Type B). All hormones were administered subcutaneously in the neck.

The lambs were fed in open sheds. All lambs received a ration of shelled yellow corn, soybean oil meal, mixed clover-timothy hay and iodized salt. In the first experiment the intake of corn and soybean oil meal was equalized and the hay fed *ad libitum*. Toward the end of the second experiment grain was fed to the various lots of lambs according to their appetite and there were therefore slight differences between lots. The average daily feed intake by treatments is given in the accompanying tables.

The lambs were weighed individually at the beginning and end of the experiments and at 14-day intervals during the trials. At the time of slaughter dressing percentage was calculated for each lamb and the carcasses were given official Federal grades.

The data on growth rate and feed efficiency were analyzed by the method of analysis of variance.

Results and Discussion

Growth Rate

The effects of the various hormones are summarized in tables 1 and 2. In trial I, stilbestrol, dienestrol in type A base, and testosterone were equally effective. All hormone-treated lambs gained significantly faster than the controls ($p<0.01$) and the controls made unusually good gains of .41 lb. per day. In trial II the initial weights of the lambs were approximately 10 lb. greater than in the first experiment. The lambs were fed for 98 days in contrast to 70 days in trial I and consequently were heavier at slaughter. The daily gains were less than in the first trial. The lambs which received 12 mg. of stilbestrol or 30 mg. of testosterone gained significantly faster than the controls ($p<0.01$) and those which received 24 mg. of stilbestrol gained significantly faster than any other group ($p<0.01$). Dienestrol in a base of low viscosity (Type B) did not have a significant effect for the 98-day period. The bimonthly weight records suggested that its effect was most marked during the first 8 weeks of the trial.

Feed Consumption and Efficiency

In the first trial daily feed intake was nearly the same for all lots. During the latter part of the second experiment concentrate was fed in amounts which the various groups would readily consume. In both experiments all hormone treated lambs required less feed per unit of gain

TABLE 1. EFFECT OF HORMONES ON GROWTH RATE, FEED CONSUMPTION AND FEED EFFICIENCY

Experiment I

Item		Group and Treatment				
		I Control	II 12 mg. Stilbestrol	III 24 mg. Stilbestrol	IV 12 mg. Dienestrol A	V 30 mg. Testosterone
Number of lambs		20	20	20	20	20
Av. initial wt.	lb.	73	73	73	74	74
Av. final wt.	lb.	101	109	108	109	109
Gain per lamb	lb.	28	36	35	35	35
Daily gain per lamb	lb.	.41	.51**	.50**	.50**	.50**
Daily feed consumption per lamb						
Shelled corn	lb.	1.25	1.26	1.24	1.26	1.26
Soybean oil meal	lb.	.10	.10	.10	.10	.10
Clover-timothy hay	lb.	2.35	2.33	2.34	2.36	2.35
Salt	lb.	.02	.02	.02	.02	.02
Total	lb.	3.72	3.71	3.70	3.74	3.73
Feed per pound of gain						
Shelled corn	lb.	3.01	2.45	2.47	2.56	2.53
Soybean oil meal	lb.	.23	.19	.10	.20	.20
Clover-timothy hay	lb.	5.67	4.45	4.63	4.80	4.72
Salt	lb.	.05	.03	.04	.04	.04
Total	lb.	8.96	7.12*	7.24*	7.60*	7.49*

Significance in comparison with controls: * $P<0.05$.
** $P<0.01$.

than the controls. The degree of significance in trial I was $p<0.05$, and $p<0.01$ for the stilbestrol and testosterone groups in trial II. The total feed requirements per unit of gain were greater in trial II than in the first experiment. This was to be expected in view of the fact that the daily gains were greater in trial I and the lambs were also marketed at lighter weights. As reviewed in the first part of the paper, most workers have found that stilbestrol administration has consistently increased rate of gain and feed efficiency in feeder lambs.

Carcass Studies

The carcass data do not lend themselves to statistical analysis. As previously reviewed, our findings and those of others have shown a consistent reduction in Federal grades following stilbestrol administration. Of the various hormones used, testosterone has had the least

TABLE 2. EFFECT OF HORMONES ON GROWTH RATE, FEED CONSUMPTION AND FEED EFFICIENCY

Experiment II

Item		Group and Treatment				
		I Control	II 12 mg. Stil-bestrol	III 24 mg. Stil-bestrol	IV 12 mg. Dienes-trol B	V 30 mg. Tes-tosterone
Number of lambs		20	20	20	20	20
Av. initial wt.	lb.	82	81	80	80	81
Av. final wt.	lb.	113	120	126	116	120
Gain per lamb	lb.	31	39	46	36	39
Daily gain per lamb	lb.	.31	.40**	.47**[2]	.37	.40**
Daily feed consumption per lamb						
Shelled corn	lb.	1.36	1.33	1.42	1.25	1.42
Soybean oil meal	lb.	.10	.10	.10	.08	.10
Clover-timothy hay	lb.	2.29	2.32	2.38	2.35	2.32
Salt	lb.	.01	.01	.01	.01	.01
Total	lb.	3.76	3.76	3.91	3.69	3.85
Feed per pound of gain						
Shelled corn	lb.	4.33	3.33	2.97	3.47	3.50
Soybean oil meal	lb.	.29	.24	.21	.22	.25
Clover-timothy hay	lb.	7.28	5.82	4.99	6.49	5.74
Salt	lb.	.03	.02	.02	.02	.02
Total	lb.	11.93	9.41**	8.19**[1]	10.20*	9.51**

Significance in comparison with controls: * $P<0.05$—** $P<0.01$.
Significance in comparison with Group IV: [1] $P<0.05$.
Significance in comparison with all other groups: [2] $P<0.01$.

effect in the reduction of carcass grade and the higher levels of stilbestrol (24 mg.) have had the most effect. This is quite different than the effects of stilbestrol in chickens in that estrogens can almost always be relied upon to increase fat deposition significantly, both visually and quantitatively in this species.

It is questionable if differences of 1 or 2 percentage points in dressing percentage are statistically significant, but the trend toward slightly reduced dressing percentage in both estrogen and androgen-treated

lambs is obvious. Preliminary studies of the carcass composition of estrogen treated cattle and sheep suggest an increase in moisture and protein and a slight reduction in fat (Stob and Andrews, 1952).

Summary

The subcutaneous implantation of 12 or 24 mg. of stilbestrol pellets significantly increased rate of gain and significantly increased feed efficiency. Carcass quality, as expressed by Federal grades, was consistently lowered.

The implantation of 30 mg. of testosterone propionate pellets significantly increased rate of gain and significantly increased feed efficiency but the magnitude of the increases was not as great as 24 mg. stilbestrol. Carcass quality was similar to the controls in both experiments.

Twelve mg. of dienestrol in one injectable base (Type A) significantly increased rate of gain and feed efficiency but in a second type of vehicle (Type B) dienestrol was not as effective. Carcass quality was inferior to the controls in both trials.

TABLE 3. EFFECT OF HORMONES ON CARCASS YIELD AND GRADE

Item	I Control	II 12 mg. Stilbestrol	III 24 mg. Stilbestrol	IV 12 mg. Dinestrol A	V 30 mg. Testosterone
			Experiment I		
Yield, in percent	50.0	49.1	48.6	48.0	47.6
Carcass grades, in percent					
U. S. Good	35	20	0	10	35
U. S. Commercial	60	65	75	90	60
U. S. Utility	5	15	25	0	5
			Experiment II		
Yield, in percent	50.3	47.6	47.9	48.7[2]	49.4
Carcass grades[1] in percent					
U. S. Choice	55	25	10	30	40
U. S. Good	40	50	55	50	60
U. S. Commercial	5	25	35	20	0

[1] The Federal grading system was changed on January 1, 1951. The 1950 grades of Good, Commercial and Utility became Choice, Good, and Commercial respectively in 1951.
[2] Dienestrol Type B was used in experiment II.

Literature Cited

Andrews, F. N., W. M. Beeson and C. Harper. 1949. The effect of stilbestrol and testosterone on the growth and fattening of lambs. JOURNAL OF ANIMAL SCIENCE 8:578.

Andrews, F. N. and W. M. Beeson. 1953. The effects of various methods of estrogen administration on the growth and fattening of wether lambs. JOURNAL OF ANIMAL SCIENCE. (In Press).

Jordon, R. M. 1950. The effect of stilbestrol on fattening lambs. JOURNAL OF ANIMAL SCIENCE 9:383.

Jordon, R. M. and W. E. Dinusson. 1950. Effect of stilbestrol on the growth rate of suckling lambs. JOURNAL OF ANIMAL SCIENCE 9:380.

O'Mary, C. C., A. L. Pope, G. D. Wilson, R. W. Bray and L. E. Casida. 1951. The effects of diethylstilbestrol, testosterone and progesterone on growth and fattening, and on certain carcass characteristics of western lambs. JOURNAL OF ANIMAL SCIENCE 10:1079.

Perry, T. W., F. N. Andrews and W. M. Beeson. 1951. The effects of stilbestrol on suckling lambs. JOURNAL OF ANIMAL SCIENCE 10:602.

Pope, A. L., C. C. O'Mary, W. E. Batterman, R. W. Bray and L. E. Casida. 1951. The effect of certain steroid hormones on the growth, fattening and carcass quality of heavy lambs. JOURNAL OF ANIMAL SCIENCE 9:681.

Stob, M. and F. N. Andrews. 1952. The effects of estrogens on the composition of sheep and cattle carcasses. (Unpublished data)

THE EFFECTS OF VARIOUS METHODS OF ESTROGEN ADMINISTRATION ON THE GROWTH AND FATTENING OF WETHER LAMBS[1]

F. N. ANDREWS and W. M. BEESON[2]

Purdue University, Agricultural Experiment Station

THE subcutaneous implantation of compressed stilbestrol pellets in wether lambs has consistently resulted in significantly increased rates of gain and increased feed efficiency (Andrews *et al.*, 1949; Jordan, 1950; Means *et al.*, 1952; O'Mary *et al.*, 1951; Pope *et al.*, 1950). Similar results were obtained with ewe lambs (O'Mary *et al.*, 1951). Jordan and Dinusson (1950) found no growth stimulating effects when stilbestrol was implanted in suckling lambs on pasture. Perry *et al.* (1951) reported highly significant increases in rate of gain of suckling lambs on pasture following the subcutaneous implantation of either 12 or 24 mg. of stilbestrol pellets in both ewe and wether lambs.

In poultry the continued approval of use of stilbestrol pellets for the improvement of carcass quality appears to depend in part upon the site of implantation of the pellets. At present the pellets must be placed as close to the head as possible in order that any remaining residues will be discarded with the head and neck at the time the fowl are dressed. Poultry which contain pellet residues in the edible portion of the carcass are subject to condemnation by food inspection authorities.

In poultry the period of stilbestrol treatment is relatively short—6 to 8 weeks or even less. In sheep a typical fattening period under farm conditions is from 60 to 100 days and in cattle the interval from stilbestrol implantation until slaughter may range from 90 to 150 days or even longer. The possibility that hormone pellet residues will remain with the edible carcass is less than with poultry but it is still desirable that an implantation site be chosen that will not remain as a part of the edible meat.

Another possible means of reducing hormone tissue retention is the administration of the hormones in injectable bases.

[1] Contribution from the Department of Animal Husbandry, Journal Paper No. 632, Purdue University Agricultural Experiment Station, Lafayette, Indiana.

[2] The authors express their appreciation to Wick and Fry, Inc., Cumberland, Indiana, for the stilbestrol and to the Ortho Research Foundation, Raritan, New Jersey, for the dienestrol preparation.

The purpose of this experiment was to determine the effectiveness of stilbestrol implanted at three different sites and to compare compressed stilbestrol pellets with dienestrol in two different injectable bases.

Materials and Methods

Six groups of 10 wether feeder lambs each were used. The lambs were out of western range ewes and sired by either Hampshire or Corriedale rams. The average initial weight of the lambs was 80 pounds, although the range was from 60 to 90 pounds. The duration of the experiment was 70 days. All lambs were fed, according to appetite, a ration composed of shelled corn, soybean oil meal, clover-timothy hay and iodized salt.

The lot treatments were as follows: Lot I, control; Lot II, one 12 mg. stilbestrol pellet implanted subcutaneously in the neck; Lot III, one 12 mg. stilbestrol pellet implanted in the scrotal sac cavity; Lot IV, one 12 mg. stilbestrol pellet implanted subcutaneously approximately 3 cm. below the margin of the lower eyelid; Lot V, 12 mg. of dienestrol in 1 cc. of an injectable waxy base of high viscosity (arbitrarily called Type A); Lot VI, 12 mg. of dienestrol in 0.5 cc. of an injectable base of low viscosity (arbitrarily called Type C). Both types of dienestrol were injected subcutaneously in the neck.

The lambs were weighed individually at 14-day intervals. Individual dressed weights and Federal carcass grades were obtained at slaughter. The data on gains were analyzed by the method of analysis of variance.

During the course of the experiment several lambs developed a severe, persistent diarrhea and were removed from the experiment. This was apparently due to a heavy parasitic infestation which persisted in some lambs. The number of lambs in each lot at the close of the experiment is shown in table 1.

Results and Discussion

Growth

The effects of stilbestrol and dienestrol on growth are summarized in table 1. Although, as previously mentioned, several animals were removed from the experiment during its progress, the average gains of the various lots were very satisfactory. As in previous experiments, treatment with stilbestrol, at any injection site, significantly increased rate of gain ($P<0.01$). There were no significant differences between

TABLE 1. EFFECT OF STILBESTROL AND DIENESTROL ON GROWTH AND FEED UTILIZATION OF LAMBS

(Feeding period, 70 Days)

Item		Lot and Treatment					
		I Control	II Stilbestrol Neck	III Stilbestrol Scrotum	IV Stilbestrol Eye	V Dienestrol Type A	VI Dienestrol Type C
Number of lambs		10	9	8	8	9	10
Av. initial wt.	lb.	80.8	77.1	78.4	81.5	78.2	78.9
Av. final wt.	lb.	105.5	114.2	115.2	119.0	107.6	106.0
Gain per lamb	lb.	24.7	37.1	36.8	37.5	29.4	27.1
Daily gain per lamb	lb.	.35	.53	.53	.54	.42	.39
Daily feed consumption per lamb							
Shelled corn	lb.	1.33	1.44	1.38	1.48	1.36	1.26
Soybean oil meal	lb.	.18	.18	.19	.19	.18	.18
Hay	lb.	1.62	1.65	1.63	1.66	1.55	1.62
Salt	lb.	.02	.05	.05	.04	.04	.03
Total	lb.	3.15	3.32	3.25	3.37	3.13	3.09
Feed per pound of gain							
Shelled corn	lb.	3.78	2.70	2.62	2.76	3.24	3.25
Soybean oil meal	lb.	.53	.34	.35	.35	.44	.47
Hay	lb.	4.58	3.11	3.10	3.09	3.71	4.18
Salt	lb.	.05	.10	.09	.08	.08	.09
Total	lb.	8.94	6.27	6.16	6.29	7.47	7.99

sites of implantation (neck, scrotum, or eye) in the response of the lambs to stilbestrol. The site beneath the eye is easily accessable but care must be taken not to inject too close to the eyeball and its accessory structures. Transient conjunctivitis was shown in some of the lambs. This cleared up in less than a week and purulent discharge was not encountered. With some material *not used* in this trial serious inflammation of the eye has been encountered. The scrotum is an ideal site from the standpoint of its complete severence from the edible carcass. The scrotal sac is very easily entered, no inflammation was encountered, and it did not prove to require much more time than implantation in the neck or beneath the eye. For these reasons, it would seem that the scrotum should be given serious consideration as a possible practical implantation site. In ewe lambs the mammary gland might be considered as an implantation site.

Dienestrol was administered in two different injectable bases in order to make possible the use of a conventional syringe and hypodermic needle. Neither of the dienestrol preparations proved to have a significant effect lasting for the duration of the experiment. There was an apparent growth stimulation during the first few weeks of the trial but the effect diminished with time and the total effect over the 70-day period was insignificant. In cattle (Andrews *et al.*, 1951) dienestrol compressed pellets produced results similar to stilbestrol pellets. It seems obvious that the problem of using a hormone in injectable form will necessitate the use of a base that permits slow absorption over a considerable period of time.

Feed Requirements

The use of single lots of animals does not permit statistical analysis of these data. As previously reviewed, stilbestrol has been shown to reduce the feed requirements per unit of gain significantly in both sheep and cattle. Inspection of the data in table 1 shows that there was a marked reduction in both the concentrates and roughage required per pound of gain. There is a suggestion of some increased feed efficiency in the dienestrol treated lots, but the results could hardly be regarded as of much importance.

As shown in table 1, daily feed intake was slightly greater in the stilbestrol treated lambs. It has been our observation that appetite, as measured by feed intake, is improved in stilbestrol treated sheep and cattle which are fed *ad libitum*.

Carcass Grades

The dressing percentages and carcass grades are summarized in table 2. The controls and the lot which received a 12 mg. stilbestrol pellet in the neck are similar. All other estrogen treated lots showed a reduction in carcass quality as measured by Federal carcass grades. These results are in accord with previous work at Purdue and by other workers cited in the literature review.

TABLE 2. EFFECT OF STILBESTROL AND DIENESTROL ON CARCASS YIELD AND CARCASS GRADES OF LAMBS

	Lot and Treatment					
Item	I Control	II Stil-bestrol Neck	III Stil-bestrol Scrotum	IV Stil-bestrol Eye	V Dienes-trol Type A	VI Dienes-trol Type C
Yield, in percent	44.3	43.7	44.6	44.7	44.4	43.8
Carcass grades, No. of lambs						
U. S. Choice	6	6	3	4	4	5
U. S. Good	4	3	5	3	4	3
U. S. Utility					1	2

Summary

The subcutaneous implantation of one 12 mg. stilbestrol pellet per lamb, in the neck, scrotum or beneath the eye, was equally effective in significantly improving rate of growth and feed utilization.

The scrotum provides a site of implantation in wether lambs that is effective and this part of the animal is completely discarded at the time of slaughter.

The injection of 12 mg. of dienestrol per lamb in two different injectable bases did not produce a measurable effect over a 70-day experimental period.

The carcass grades of estrogen-treated lambs tended to be inferior to those of the controls.

Literature Cited

Andrews, F. N., W. M. Beeson and C. Harper. 1949. The effect of stilbestrol and testosterone on the growth and fattening of lambs. JOURNAL OF ANIMAL SCIENCE 8:578.

Andrews, F. N., W. M. Beeson and F. D. Johnson. 1951. Effect of hormones on the growth and fattening of yearling steers. Purdue Univ., Animal Husbandry Dept. Mimeo No. A. H. 60.

Jordon, R. M. 1950. The effect of stilbestrol on fattening lambs. JOURNAL OF ANIMAL SCIENCE 9:383.

Jordon, R. M. and W. E. Dinusson. 1950. Effect of stilbestrol on the growth rate of suckling lambs. JOURNAL OF ANIMAL SCIENCE 9:380.

Means, T. M., F. N. Andrews and W. M. Beeson. 1953. The effect of hormones on the growth and fattening of lambs. JOURNAL OF ANIMAL SCIENCE. (In Press)

O'Mary, C. C., A. L. Pope, G. D. Wilson, R. W. Bray and L. E. Casida. 1951. The effects of diethylstilbestrol, testosterone and progesterone on growth and fattening, and on certain carcass characteristics of western lambs. JOURNAL OF ANIMAL SCIENCE 10:1079.

Pope, A. L., C. C. O'Mary, W. E. Batterman, R. W. Bray and L. E. Casida. 1951. The effect of certain steroid hormones on the growth, fattening and carcass quality of heavy lambs. JOURNAL OF ANIMAL SCIENCE 9:681.

Perry, T. W., F. N. Andrews and W. M. Beeson. 1951. The effects of stilbestrol on suckling lambs. JOURNAL OF ANIMAL SCIENCE 10:602.

PROTEIN REQUIREMENTS OF EWES DURING BREEDING AND PREGNANCY[1]

EARLE W. KLOSTERMAN,[2] D. W. BOLIN, M. L. BUCHANAN, F. M. BOLIN, and W. E. DINUSSON

North Dakota Agricultural Experiment Station

IN the past only very limited information has been available on the protein requirements of pregnant ewes. The National Research Council (Pearson, *et al.*, 1949) has recommended allowances for this nutrient based largely upon information obtained from experiments with cattle. Recent publications (Van Horn, *et al.*, 1950, 1951; Jordan, 1950; Klosterman and co-workers, 1951a; Slen and Whiting, 1952) have indicated that these allowances may be somewhat higher than required. It is necessary, however, for such recommended allowances to include some safety factor to meet adequately variations in environment, feeds, and individual animals.

In previous feeding experiments (Klosterman *et al.*, 1951a) no consistent differences were noted in lamb production from pregnant ewes fed rations which supplied from 0.18 to 0.34 pound digestible crude protein per ewe daily. The National Research Council (Pearson *et al.*, 1949) has recommended, for ewes of similar weight, 0.20 pound digestible crude protein during the first 100 days of gestation and 0.25 pound during the last six weeks of pregnancy. In these feeding experiments, the low-protein, basal ration consisted of grass hay, yellow corn, and minerals. These investigations have been continued to study the performance of ewes on rations lower in protein.

Procedure

Experiments were conducted during the 1950–51 and the 1951–52 breeding and pregnancy periods. One hundred and twenty ewes of various ages and breeding were included in each experiment. These ewes included grade Hampshires, Columbias, and Rambouillets and varied in age from yearlings to aged but sound-mouthed ewes. In each experiment they were divided into six lots as nearly equal as possible with respect to breeding and age.

The ewes were allotted and fed the experimental rations for approxi-

[1] Contribution from the North Dakota Agricultural Experiment Station. Published with the approval of the Director of the Station.

[2] Present address, Ohio Agricultural Experiment Station, Wooster, Ohio.

mately three weeks prior to the start of breeding. In both experiments three pure-bred Columbia rams were used. The rams were alternated among lots at 12-hour intervals, in such a way that each ram spent the

TABLE 1. RATIONS FED, GAIN OF EWES, AND LAMBS PRODUCED
(Experiment 1, 1950–1951)

Lot number	1	2	3	4	5	6
Total protein in ration, pct.	13.23	10.15	6.97	13.43	10.12	6.97
Digestible protein, lb./ewe daily	0.28	0.19	0.10	0.29	0.19	0.10
Digestible D.M., lb./ewe daily	1.53	1.52	1.51	1.55	1.53	1.51
Average daily ration, lb.:						
Wheat straw	2.09	2.09	2.09	2.09	2.09	2.09
Cane molasses	0.32	0.32	0.32	0.32	0.32	0.32
Yellow corn	0.20	0.50	0.79	0.79	0.79	0.79
Soybean oil meal	0.59	0.29	....	....	....	....
Urea	....	....	....	0.0786	0.0393	....
Alfalfa	0.19	0.19	0.19	0.19	0.19	0.19
Bone meal	0.01	0.01	0.01	0.01	0.01	0.01
Salt	0.01	0.01	0.01	0.01	0.01	0.01
Number ewes per lot	20	20	20	20	20	20
Death loss, number ewes	1	0	5	2	1	2
Average initial weight, lb.	120.8	120.1	120.1	120.4	119.7	119.7
Average gain, ewes lambed, lb.	29.7	28.8	33.7	34.2	26.6	34.0
Average fleece weight, lb.	8.6	9.1	8.1	9.0	8.9	8.7
Lamb Production:						
Number live lambs born	26	20	17	24	23	22
Number lambs born dead	0	0	0	0	1	0
Number ewes lambed	19	17	13	17	18	16
Average birth weight, lb.:						
Singles	10.6	11.3	11.6	11.7	10.8	11.2
Twins	9.8	8.4	9.2	8.9	8.6	8.2
Triplets	7.5					
Number lambs died first 30 days	7	2	3	3	10	4
Average weight at 30 days, lb.:						
Singles	24.8	28.0	26.1	26.0	26.7	27.8
Twins	19.8	21.0	18.6	19.1	20.6	15.2
Average pounds lamb at 30 days per ewe lambed	21.6	28.0	25.8	27.3	18.6	23.4

same amount of time in each lot. The rams were removed after a 30-day breeding season.

The ewes were kept on their respective rations until they lambed. The average daily rations are given in tables 1 and 2. The amounts of feed listed are averages for the entire feeding period, and are the

amounts offered rather than consumed. The molasses was mixed with the wheat straw by pumping it into the blower of the chopper at the time the straw was chopped. This straw-molasses mixture was weighed and hand-fed twice daily. The total weights of straw and molasses

TABLE 2. RATIONS FED, GAIN OF EWES, AND LAMBS PRODUCED
(Experiment 2, 1951–1952)

Lot number	1	2	3	4	5	6
Total protein in ration, pct.	10.71	7.64	4.57	11.15	7.90	4.57
Digestible protein, lb./ewe daily	0.27	0.15	0.06	0.29	0.16	0.06
Digestible D.M., lb./ewe daily	1.38	1.39	1.40	1.44	1.42	1.40
Average daily ration, lb.:						
Wheat straw	2.28	2.28	2.28	2.28	2.28	2.28
Cane molasses	0.57	0.57	0.57	0.57	0.57	0.57
Yellow corn	0.04	0.39	0.74	0.74	0.74	0.74
Soybean oil meal	0.70	0.35	....	....	....	....
Urea	....	....	....	0.0946	0.0473	....
Bonemeal	0.01	0.01	0.01	0.01	0.01	0.01
Salt	0.01	0.01	0.01	0.01	0.01	0.01
Number ewes per lot	20	20	20	20	20	20
Death loss, number ewes	1	1	1	0	0	4
Average initial weight, lb.	129.0	129.4	127.0	126.4	128.4	128.6
Average gain, ewes lambs, lb.	24.2	20.1	9.9	14.2	17.6	10.5
Average fleece weight, lb.	10.6	9.6	9.4	9.2	9.3	8.8
Lamb Production:						
Number live lambs born	23	20	20	19	23	15
Number lambs born dead	0	0	2	2	2	0
Number ewes lambed	19	15	18	15	19	13
Average birth weight, lb.:						
Singles	10.5	10.5	10.6	10.8	10.8	9.5
Twins	9.1	7.5	7.5	8.3	8.0	8.6
Number lambs died first 30 days	4	7	5	4	7	2
Average weight at 30 days, lb.:						
Singles	25.5	26.2	24.9	27.5	27.1	26.2
Twins	22.1	20.0	20.6	19.4	20.9	19.5
Average pounds lamb at 30 days per ewe lambed	24.7	21.1	19.8	24.3	21.5	25.2

which were chopped together were used to determine the proportion of each that was fed daily. Some of the straw-molasses mixture was wasted in all lots but to a greater extent in Lots 3 through 6. The ewes fed soybean oil meal in Lots 1 and 2 consumed the straw somewhat more readily than those fed either the low-protein rations or those supplemented with urea. In the 1950–51 experiment the rations which

contained urea were supplemented with DL-methionine.[3] Lot 4 was fed 0.1 percent methionine, and Lot 5 received three-fourths that amount.

As each ewe lambed it was placed on a ration common to all the ewes during lactation. This ration, which was adequate according to present recommendations, was composed of grass hay, yellow corn, soybean oil meal, and minerals. As soon as the lambs would eat they were allowed access to cracked yellow corn and alfalfa hay in a creep. No lambs were killed intentionally and no supplemental milk was supplied to any of the lambs.

All ewes were bled for blood protein determinations at three intervals during the gestation period. The results of these analyses showed some reduction in oxyhemoglobin and serum albumins with reduced amounts of nitrogen in the ration. These observations are in agreement with former published results (Klosterman *et al.*, 1950).

At three times during the pregnancy period two representative, mature ewes from each lot were used in nitrogen balance experiments to determine, as nearly as possible, the amount of nitrogen the ewes were storing or losing. These experiments were conducted immediately after breeding, during mid-gestation and just prior to lambing. One previous nitrogen balance experiment with pregnant ewes (Klosterman *et al.*, 1951b) showed that the ewes remained in positive balance when fed approximately one-half the present recommended amounts of digestible crude protein.

In each balance study the ewes were placed in metabolism cages and fed the same rations they were receiving in their respective lots. The rations were not alternated so that each ewe received the same feed throughout pregnancy. After the amounts of feed that each individual ewe was consuming had been standardized a seven-day collection was made. Some of the ewes ate less feed while in the cages than the average offered the ewes in the experimental lots.

Results

The gains of the ewes and wool and lamb production obtained during the 1950–51 experiment are presented in table 1. Statistical analyses showed no significant differences between levels of nitrogen-fed with respect to the gain of the ewes, fleece weight, birth weight of lambs, or thirty-day weight of lambs. It will be noted, however, that the ewes in Lots 3 and 6 which were fed the low level of nitrogen sheared

[3] The urea, du Pont "Two-sixty two", and methionine used in these experiments were generously supplied by E. I. du Pont de Nemours and Co., Inc., Wilmington, Delaware.

slightly lighter fleeces. Analysis of the thirty-day weights of the lambs showed a significant interaction between level of protein and number of lambs (singles compared to twins). The thirty-day weights of the twin lambs were affected more by level of protein than were the weights of the single lambs. The twin lambs from the ewes fed the low level of protein tended to be lighter than the twin lambs from the ewes fed the two higher levels of nitrogen. These differences in weights of twin lambs were too variable, however, to show significance. The difference between Lots 3 and 6, which had been fed identical rations, was greater than the difference between Lot 3 and any other lot.

The results of the second experiment conducted during 1951–52 are presented in table 2. The rations fed during this experiment varied from the previous one in that no alfalfa was included. Also, the amounts of digestible crude protein and digestible dry matter were somewhat lower. These digestible nutrients were calculated from digestion coefficients obtained in the metabolism experiments and the amounts of feed offered to the lots. They are not an accurate measure of the actual consumption, however, in that the ewes fed the low protein ration and those fed the rations supplemented with urea wasted more of the straw-molasses mixture than those fed the rations which included soybean oil meal. No accurate measure could be made of the wastage because the straw was finely chopped and became mixed with the bedding. The amounts offered were not reduced as every effort was made to maintain maximum consumption. The difference in wastage between lots was greater in this experiment than in the previous one when a small amount of alfalfa was fed.

Statistical analysis of the gains made by the ewes in this second experiment showed a significant difference between levels of nitrogen-fed. It is believed that these differences in gain were due primarily to differences in feed consumption. The gains made were also somwhat lower than those made by the ewes in the 1950–1951 experiment.

The fleece weights of the ewes fed the low-protein rations again averaged slightly lighter but the differences were not significant. There were no significant differences between lots or levels of nitrogen with respect to birth or thirty-day weights of the lambs produced.

The results obtained from Lots 1 and 4, 2 and 5, and 3 and 6 for both years have been averaged together to obtain the data presented in table 3. The combined results of the two experiments showed no significant differences between the three levels of nitrogen in any of the measures of the value of the rations fed.

Although not statistically significant, some differences between corresponding results will be noted in table 3. The ewes fed the lowest level of nitrogen sheared the lightest fleeces and their twin lambs were the lightest at thirty days of age. The ewes fed the highest level of nitrogn gave birth to the heaviest twin lambs but, compared to the

TABLE 3. GAIN AND LAMB PRODUCTION OF EWES FED THREE LEVELS OF NITROGEN

(Average Experiments 1 and 2)

Average of rations	High		Medium		Low	
Total protein in ration, pct.	12.13		8.95		5.77	
Digestible protein, lb./ewe daily	0.28		0.17		0.08	
Digestible D.M., lb./ewe daily	1.48		1.47		1.46	
Number of ewes	80		80		80	
Death loss, number ewes	4		2		12	
Average initial weight, lb.	124.2	(80)[1]	124.4	(80)	123.9	(80)
Average gain, ewes lambed, lb.	26.0	(70)	23.3	(69)	21.6	(60)
Average fleece weight, lb.	9.3	(76)	9.2	(77)	8.8	(66)
Lamb Production:						
Number live lambs born	92		86		74	
Number lambs born dead	2		3		2	
Number ewes lambed	70		69		60	
Average birth weight, lb.:						
Singles	10.9	(47)	10.9	(48)	10.7	(40)
Twins	9.0	(42)	8.1	(38)	8.3	(34)
Triplets	7.5	(3)				
Number lambs died first 30 days	18		26		14	
Average weight at 30 days, lb.:						
Singles	25.9	(40)	27.1	(46)	26.1	(40)
Twins	19.8	(34)	20.6	(14)	17.4	(20)
Average pounds lamb at 30 days per ewe lambed	24.4		22.2		23.2	

[1] Figures in parenthesis are number of observations.

ewes fed the medium level, this advantage was not reflected in the thirty-day weights. The thirty-day weights of twin lambs, as presented, are only for the lambs that were raised as twins. When one lamb died shortly after birth, its twin was calculated as a single. Likewise, one lamb of the set of triplets died soon after birth; so the remaining two were considered as twins in the thirty-day weights.

A difference in death loss of ewes fed the three levels of nitrogen was apparent. Whether or not such losses should be attributed to the rations

fed is always difficult to determine. Two ewes on the high level, one on the medium, and one on the low level of nitrogen died from complications arising from a prolapse of the uterus or dystocia. It is doubtful whether these complications were related to the rations fed. Trichloroethylene extracted soybean oil meal was fed in the 1951–52 experiment, which may have caused the death of one of the ewes fed the higher level. One of the ewes on the low level was killed while being drenched for internal parasites. One of the ewes fed the high, one the medium, and six fed the low level of nitrogen showed edema of the lungs or pneumonia upon autopsy. The much higher death loss of ewes fed the low-nitrogen rations suggests that this lung condition may have been predisposed by the ration fed. Four of the ewes fed the low-protein ration in the 1950–51 experiment died very suddenly a short time after they were started on their experimental ration. Upon autopsy all of these ewes were found to have pasteurella infections. Since all of these deaths occurred on the same ration and shortly after the ewes had been placed on a very low-protein ration, it may be possible that the ration was a predisposing factor (Bolin, 1950; Bolin and Eveleth, 1951). No symptoms of pregnancy disease were noted in any of the ewes.

The number of lambs born, number of lambs at thirty days, and the number of ewes that lambed are presented in the three tables. Any desired lambing percentage can be calculated from these data. When based on the number of lambs born and the number of ewes alive at lambing, the percentages were 124, 114, and 112 for the high, medium, and low levels, respectively. When based on the number of lambs alive at thirty days and the number of live ewes at lambing time these percentages were 97, 77, and 88. The ewes fed the highest level of nitrogen had the highest percentage in both instances. However, when the similarity of number of lambs born on the medium and low levels and the superiority of the low level over the medium level at thirty days are considered, it is difficult to determine whether or not the amount of nitrogen fed to the ewes had any influence on lambing percentage. The most important factors which influenced the number of lambs produced were the higher death loss of ewes in the lots fed the low level and the higher death loss of lambs from the ewes fed the medium levels of nitrogen.

The death loss of lambs which occurred was not the result of any one major factor or disease. Neither could the higher death loss of lambs from the ewes fed the medium levels of nitrogen be ascribed to

any one cause. Some of these factors were: weak lambs at birth, insufficient milk of the dam, failure of ewes to own their lambs, pneumonia and a few anatomical abnormalities. No consistent differences were found between lots in respect to these factors. Special effort was made to care for the ewes and lambs except no supplemental milk was given and no effort was made to transfer lambs to different ewes.

The results obtained from the nitrogen metabolism experiments are presented in table 4. These are averages of both years, or experiments, and do not include results from ewes that did not eat satisfactorily while in the metabolism cages. The average body weights of the ewes were 130 pounds during early and mid-gestation and 140 pounds during late pregnancy. The present recommended daily amounts of digestible crude protein for such ewes are 0.20 pound and 0.24 pound, respectively (Pearson *et al.*, 1949).

No marked differences were noted in nitrogen balance between ewes fed soybean oil meal and those fed urea. Although a reversal type experiment may possibly have shown some difference between these two sources of nitrogen, it was not apparent in these studies. The main objective of these investigations was to determine the amount of nitrogen retained at various levels of intake. Therefore, the results have been analyzed without regard to source of nitrogen.

It will be noted in table 4 that the apparent digestibility of nitrogen decreased as the nitrogen intake decreased in all three periods. This marked reduction in digestibility can be explained by the fact that a higher proportion of the total nitrogen in the low-protein rations came from the relatively undigestible wheat straw. The digestion coefficients obtained for dry matter were somewhat variable and show no definite trend with regard to nitrogen intake.

The results from the three balance periods were studied in an analysis of covariance with regard to digestible dry matter intake and nitrogen balance. The analysis table was set up to determine the relationship of these items to level of nitrogen intake, stage of pregnancy and the interaction between the two. As would be expected from observation of the data, there was a highly significant difference in digestible dry matter intake between the three balance periods. There was no significant difference in digestible dry matter intake between levels of nitrogen fed nor in the interaction of level of nitrogen and period of pregnancy.

Analysis of the totals for the three balance periods showed the differences which occurred in nitrogen retention between the three levels of nitrogen fed not to be significant. There was a significant difference in

TABLE 4. AVERAGE DAILY AMOUNTS OF DIGESTIBLE PROTEIN, DIGESTIBLE DRY MATTER, AND NITROGEN BALANCE DURING EARLY, MID, AND LATE GESTATION

Stage	Early-gestation			Mid-gestation			Late-gestation		
Average of rations	High	Medium	Low	High	Medium	Low	High	Medium	Low
Lots	1 & 4	2 & 5	3 & 6	1 & 4	2 & 5	3 & 6	1 & 4	2 & 5	3 & 6
Number of ewes	6	8	8	7	8	8	7	7	8
Average feed intake, lb.	2.96	2.77	2.72	3.17	2.88	2.85	3.65	3.53	3.36
Total crude protein, pct.	13.35	10.12	6.11	13.82	11.01	7.16	11.56	8.88	6.09
Digestible protein, lb.	0.26	0.16	0.06	0.30	0.20	0.10	0.26	0.16	0.07
Digestible dry matter, lb.	1.12	1.15	1.08	1.51	1.44	1.44	1.57	1.53	1.38
Nitrogen intake, grams	26.41	19.27	11.44	30.01	22.32	14.28	28.91	19.48	13.61
Fecal nitrogen, grams	7.83	7.67	6.97	8.74	7.94	6.80	10.06	8.33	8.34
Urinary nitrogen, grams	17.14	11.83	4.50	16.32	10.83	3.93	12.66	7.61	4.84
Nitrogen balance, grams	1.44	—0.23	—0.03	4.95	3.55	3.55	6.19	3.54	0.43
Apparent digestibility of nitrogen, pct.	70	60	39	71	64	52	65	57	39
Apparent digestibility of dry matter, pct.	52	53	50	62	63	65	58	65	57

nitrogen balance between the three collection periods and also in the interaction between levels of intake and periods. This significant interaction would be expected from observation of the data as no marked differences were noted in the first two periods but a considerable difference in nitrogen retention between levels of nitrogen intake was observed in the third period.

A highly significant correlation ($r=0.69$) was found to exist between the amount of dry matter digested and the amount of nitrogen retained. Covariance analysis showed that the amount of dry matter digested had a greater influence upon nitrogen retention than the level of nitrogen fed. This was especially true during the first two periods when the level of nitrogen fed had no significant effect upon the amount of nitrogen retained. A relationship between energy intake and nitrogen retention has been demonstrated in growing dairy calves (Lofgreen and co-workers, 1951) and in numerous other species as reviewed by Munro (1951).

Discussion

The results presented in this paper and those published previously (Klosterman *et al.*, 1951a) have shown the difficulty encountered in establishing exact nutrient requirements for pregnant ewes. Heredity or other individual characteristics of ewes, such as breeding performance, twinning, uniformity of twin lambs, ability to produce milk and mother instinct are difficult to control. It was found that some of these characteristics varied from year to year within the same individual even though fed a similar ration. These factors lead to results with considerable variability. The ewes in these investigations also varied considerably in type and age. In each experiment the lots were as nearly equal as possible in these respects. However, more consistent results might be obtained with a more uniform group of ewes.

The fleece weights obtained in these experiments were undoubtedly affected the most by the variation in type of ewe. A more uniform group of ewes might well have shown significant differences in wool production between the groups fed different levels of nitrogen. It should also be remembered that over one-half of the annual fleece weight recorded was produced on rations other than those studied in these investigations.

The results obtained show that it is difficult to influence lamb production significantly by the amount of protein fed to pregnant ewes as

long as the energy intake remains relatively constant. The metabolism experiments which were conducted emphasize the importance of an adequate energy intake in the proper utilization of nitrogen. In these experiments, non-protein nitrogen, as supplied by urea, was not as effective as soybean oil meal in maintaining feed intake when added to a very low protein ration. This was true even though metabolism experiments showed no marked difference between the two in utilization of the nitrogen consumed.

The results obtained on the low-protein rations in these experiments are not in complete agreement with those of Slen and Whiting (1952). The two experiments are not directly comparable, however, since Slen and Whiting fed the same low-protein ration throughout pregnancy and lactation. In addition, they destroyed at birth a number of lambs on the low-protein rations because the ewes had insufficient milk to nurse them. A number of the ewes in the present experiments showed little promise of adequate milk production at the time of lambing but produced a surprising amount when placed on a ration adequate for lactation.

Even though none of the differences in lamb or wool production found in these experiments proved to be statistically significant, it is not believed that rations as low in protein as the basal ration used in these investigations should be recommended. A larger number of ewes, more experiments, or a more uniform group of ewes might prove some of the differences which did occur to be significant. The high death loss of ewes on the low-protein ration may also have been predisposed to some extent by the ration fed.

It does appear, however, that the results obtained in these experiments combined with those reported in other publications (Jordan, 1950; Van Horn and co-workers, 1951; Klosterman *et al.*, 1951a, 1951b; and Slen and Whiting, 1952) indicate that the present National Research Council recommendations for digestible crude protein (Pearson *et al.*, 1949) may be safely decreased. This would be true when careful attention is given to other essential nutrients and an optimum energy intake in particular. The results of the nitrogen metabolism experiments indicate that, with adequate amounts of energy, mature pregnant ewes will retain considerable amounts of nitrogen on rations much lower in protein than those presently recommended. The present allowances for total digestible nutrients appear to be fully adequate to promote this storage of nitrogen.

Summary

Two experiments designed to study the protein requirements of pregnant ewes are reported. Six lots of twenty ewes each were included in each experiment. In the first experiment rations which contained approximately 7, 10, and 13 percent total crude protein were compared and in the second rations containing 5, 8, and 11 percent protein.

No statistically significant differences were found between the various rations in fleece weight, birth weight of lambs, or weight of lambs at thirty days of age. Some trends were noted, however, in that the ewes fed the lowest levels of nitrogen tended to shear lighter fleeces and their twin lambs weighed slightly less at thirty days.

The death loss of ewes was somewhat higher on the low-protein rations. The low nitrogen intake may have been a predisposing factor in a number of these deaths.

Nitrogen balance experiments showed no significant differences in nitrogen retention between the three levels of nitrogen intake during early and mid gestation. In late pregnancy the ewes fed the higher levels of nitrogen retained significantly larger amounts.

A highly significant correlation ($r=0.69$) was found to exist between nitrogen retention and digestible dry matter intake. Covariance analysis showed that, at the levels fed in these investigations, the amount of nitrogen stored was influenced more by the amount of dry matter digested than by the amount of nitrogen fed.

The results obtained indicate that present recommendations with respect to amounts of crude protein for pregnant ewes may be decreased when the rations fed are adequate in other nutrients.

Literature Cited

Bolin, F. M. 1950. Factors predisposing domestic fowls to pasteurellosis. Proc. No. Dakota Acad. of Sci., 4:16.

Bolin, F. M., and D. F. Eveleth. 1951. The use of biological products in experimental fowl cholera. Proc. Eighty-eighth Annual Meeting of the Am. Vet. Med. Assoc., pp. 110–112.

Jordan, R. M. 1950. Rations for wintering breeding ewes. So. Dakota Agr. Exp. Sta. Bul. 399, 8 pp.

Klosterman, E. W., D. W. Bolin, M. L. Buchanan, and F. M. Bolin. 1950. The blood proteins of pregnant ewes and how they are affected by protein in the ration. JOURNAL OF ANIMAL SCIENCE 9:180.

Klosterman, E. W., M. L. Buchanan, D. W. Bolin, and F. M. Bolin. 1951a. Levels and sources of protein in rations for pregnant ewes. JOURNAL OF ANIMAL SCIENCE 10:257.

Klosterman, E. W., D. W. Bolin, Earl L. Lasley, and W. E. Dinusson. 1951b. The effect of methionine supplementation upon the utilization of pea and alfalfa proteins by sheep. JOURNAL OF ANIMAL SCIENCE 10:439.

Lofgreen, G. P., J. K. Loosli, and L. A. Maynard. 1951. The influence of energy intake on the nitrogen retention of growing calves. Jour. Dairy Sci. 34:911.

Munro, H. N. 1951. Carbohydrate and fat as factors in protein utilization and metabolism. Physiol. Rev. 31:449.

Pearson, P. B., W. C. Kammlade, J. I. Miller, and R. F. Miller. 1949. Recommended nutrient allowances for sheep. National Research Council, 24 pp.

Slen, S. B., and F. Whiting. 1952. Lamb production as affected by level of protein in the ration of the mature ewe. JOURNAL OF ANIMAL SCIENCE 11:166.

Van Horn, J. L., W. H. Burkitt, G. F. Payne, G. C. Hughes, and F. S. Willson. 1950. Nutritional requirements of ewes wintered under range conditions, I. Protein requirements. Mont. Agr. Exp. Station, Mimeo. Rept.

Van Horn, J. L., W. H. Burkitt, G. F. Payne, G. C. Hughes, and F. S. Willson. 1951. Nutritional requirements of ewes wintered under range conditions, I. Protein requirements. Mont. Agr. Exp. Sta. Circular 56.

THE UTILIZATION OF AMMONIATED INDUSTRIAL BY-PRODUCTS AND UREA BY SHEEP[1]

A. D. TILLMAN[2] and R. W. SWIFT[3]

The Pennsylvania State College

CONSIDERABLE interest in the use of non-protein nitrogen compounds, such as urea in ruminant nutrition, was stimulated by the excellent review of Krebs (1937). He concluded that the value of urea nitrogen in replacing vegetable protein for lactation and growth was not well established, and suggested long time growth experiments. Hart and co-workers (1939) conducted two long-time growth experiments with dairy calves in which they found that a ration containing 43 percent of the nitrogen from urea was nearly as valuable as one in which 66 percent of the nitrogen came from casein.

Goss (1943), McNaught and Smith (1947) and Reid (1951) have reviewed the literature concerning the utilization of urea by ruminant animals. In these more recent reviews, it is pointed out that the main problem in ruminant nutrition is one of supplying an ideal medium for the growth of microorganisms living in the rumen or paunch and that it is these microorganisms that can transform elemental nitrogen into a form that is utilizable by the host. The recent works by Burroughs *et al.* (1951) and Arias *et al.* (1951) using an artificial rumen technique support this idea. The reports that methionine (Loosli and Harris 1945) aided the utilization of urea in a ration composed of natural foodstuffs and that sulfur in the form of inorganic sulfates increased the utilization of urea nitrogen in purified rations (Thomas *et al.* 1951) lends further support to the hypothesis that synthesis of essential amino acids from inorganic sources occurs in the rumen. Loosli *et al.* (1950) also showed that 10 essential amino acids are synthesized in the rumen.

In recent years, there has been considerable interest in the feeding

[1] Authorized for publication on August 14, 1952 as paper No. 1751 in the Journal Series of the Pennsylvania Agricultural Experiment Station.

[2] This study was conducted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Animal Nutrition. Present address, Oklahoma A & M College, Stillwater, Oklahoma.

[3] The authors wish to acknowledge the technical assistance of G. P. Barron, R. L. Cowan, R. H. Ingram, K. H. Maddy, J. J. Rovics, and J. A. Uram.

[4] Errata, "Further Determinations of the Nutritive Values of Forages", Swift *et al.*, JOURNAL OF ANIMAL SCIENCE 11:389. May, 1952.

On page 393, table 2, the crude protein value for timothy hay should be 12.01% instead of 24.84%; on page 394, table 3, the digestibility of the crude protein of the timothy hay should be 63.6% instead of 82.4% and the N-free extract 68.9% instead of 56.7%. On page 397, line 3 from bottom, the value 5.3 should read 3.5. On page 397, line 6 from bottom, the words, "except the nitrogen-free extract" should be omitted.

value of ammoniated industrial by-products. Millar (1941, 1942a, 1942b, 1944) developed a procedure for ammoniating products of this nature, and reported that the nitrogen contained in these compounds was utilized by growing dairy calves. Knodt (1951) showed that ammoniated cane molasses and ammoniated condensed distillers molasses solubles gave good results when fed to dairy calves. In a digestibility trial, he found the nitrogen from the ammoniated products to be as well digested as that from soybean meal. Magruder *et al.* (1951) reported that ammoniated cane molasses, when fed to milk cows at a 10 percent level of the basic grain ration, gave excellent results in reference to the production of milk and changes in body weight. These workers also fed ammoniated wood molasses to growing dairy heifers and obtained favorable results. Culbertson (1950) and Tillman and Kidwell (1951) obtained good growth when the ammoniated products were included in the rations of beef animals.

The purpose of this experiment was to evaluate ammoniated condensed distillers molasses solubles, ammoniated cane molasses, and urea when these compounds furnished a part of the nitrogen in rations composed primarily of natural feedstuffs.

Materials and Methods

With the above objective in mind it was decided to use the carbon-nitrogen balance method to evaluate the utilization by sheep of the carbon, nitrogen and energy contained in the different rations. The large respiration calorimeter at this institution, originally designed for use with cattle, but as modified (Swift *et al.* 1948) to accommodate four sheep as a unit, was used. By means of this apparatus the production of carbon dioxide and methane was determined.

After being given a drench of phenothiazine preparation, 10 Hampshire wether lambs were divided into groups of five on the basis of live weight. Feces and urine were collected quantitatively from each animal in these groups. Four of each group were used as a unit in the calorimeter for the determination of carbon dioxide and methane. The experimental period for each group consisted of a transition period of 7 days, a preliminary period of 7 days and a period of 11 days for the collection of feces and urine and finally a period in the respiration chamber of 48 hours. The sheep were kept in individual metabolism crates during the entire experimental period. The metabolism crates, described by Bratzler (1951) did not require harness; therefore, the animals were unhampered in freedom of movement within the crate.

Heat production was computed by the balance of carbon and nitrogen method in all periods and was also determined by direct calorimetry in period 1. This afforded opportunity to compare direct and indirect calorimetry and to acquaint the operators with the details of direct calorimetry. Collection periods ended before the sheep entered the calorimeter. While in the chamber the four sheep, in individual pens, stood on a heavy wire screen floor beneath which was placed a 3-inch layer of sawdust to absorb the urine. The animals were fed twice daily and water was available at all times. A correction was made for the heat and CO_2 produced by the operator entering the chamber to feed the sheep.

The main objective in compounding the experimental rations was to include the test feeds with a basal mixture to form a ration supplying equal amounts of energy and nitrogen. The basal mixture contained the following feeds in percent: timothy hay, 20.50; alfalfa hay, 20.50; shelled yellow corn, 57.50; mineral mixture, 1.45; and vitamins A and D feeding oil, 0.05. This mixture was ground in a hammer mill through a 7/16 inch screen and blown directly into a vertical mixer and thoroughly mixed. It was then stored until used in sealed containers in a cool place. The rations were compounded in such a way that each test feed, when combined with cerelose and/or fed in different amounts would supply equal amounts of energy and nitrogen. The composition of the rations is shown in table 1. All of the ration needed during the experimental period, was weighed into individual paper bags containing enough feed for one feeding of each sheep and stored until used. Samples for analysis and for the storage test were taken at this time. These samples were finely ground in a Wiley mill and stored in ground-glass-stoppered bottles. The daily intake of feed is shown in table 2.

As a constant feed intake is necessary for digestibility and metabolism studies, the intake of feed is necessarily lower than the maximum amount the animals will consume. For this reason a 32-day feeding trial was conducted to determine the palatability or acceptability of rations that contained ammoniated CDMS and ammoniated cane molasses at the level of 10 percent of the grain ration. Ration 1 in this test contained in percent rolled oats, 25.00; cracked yellow corn, 54.00; soybean oil meal 11.00; and ammoniated CDMS 10.00 while ration 2 contained rolled oats, 25.00; yellow corn 54.93; soybean meal 10.07 and ammoniated cane molasses 10.00. Salt, water and mineral supplement were given free choice. Two sheep were given each ration for 32 days; the first 10 days being used to increase gradually the amount of feed while

TABLE 1. SCHEDULE OF EXPERIMENTATION AND COMPOSITION OF RATIONS

Ration and period	Daily ration per sheep						Collection period		Calorimeter period	
	Basal mixture	Ammoniated CDMS	Ammoniated cane molasses	Urea (262)	Soybean oil meal	Cerelose	Start 1951–1952	End 1951–1952	Start 1952	End 1952
	gm.	gm.	gm.	gm.	gm.	gm.				
1	765.0	127.4	—	—	—	7.6	Dec. 28	Jan. 8	Jan. 9	Jan. 11
2	765.0	—	99.3	—	—	5.7	Jan. 4	Jan. 15	Jan. 16	Jan. 18
3	765.0	—	—	6.1	—	64.9	Jan. 25	Feb. 5	Feb. 6	Feb. 8
4	765.0	—	—	—	33.8	47.2	Feb. 1	Feb. 12	Feb. 13	Feb. 14

during the last 22 days they were fed *ad libitum*. The animals were kept in the previously described metabolism crates but neither collection of feces nor urine was made.

Feces were sampled for analysis as described by Swift *et al.* (1947). The daily urine was collected in a sulfuric acid medium, prepared by adding 10 ml. of a 1:1 solution to about 500 ml. of water, and made up to a definite weight (3500 gm.). A 200 ml. aliquot was taken daily to

TABLE 2. DAILY INTAKE OF RATION CONSTITUENTS

Constituent		Ammoniated CDMS ration	Ammoniated cane molasses ration	Urea ration	Soy-bean ration
Air dry weight fed daily	gm.	900.0	870.0	836.0	846.0
Dry matter	%	85.4	86.1	89.8	89.4
	gm.	768.4	749.0	750.8	756.2
Crude protein	%	10.5	10.8	11.6	11.5
	gm.	94.5	94.1	97.2	97.3
Ash	%	6.4	5.2	5.1	4.7
	gm.	57.9	46.0	42.7	39.5
Ether extract	%	3.0	2.5	3.5	3.0
	gm.	27.3	21.6	28.8	25.4
Crude fiber	%	11.2	12.0	13.5	13.1
	gm.	101.0	104.6	113.2	110.4
NFE	%	54.2	55.6	56.1	57.2
	gm.	487.8	483.8	468.8	483.7
Energy	cal/gm.	3712	3759	3900	3949
	Cals.	3341	3270	3260	3341
Carbon	%	37.5	37.4	38.8	40.0
	gm.	337.1	325.7	324.7	338.2

make a composite for analysis of carbon and nitrogen. Also samples of untreated urine from the sheep receiving the ammoniated CDMS ration were dried for the determination of energy and nitrogen. Energy values (large calories) obtained by the bomb calorimeter were corrected for loss of drying by multiplying the nitrogen lost in grams by 5.447 (Swift *et al.* 1948). This is based on the nitrogen and energy content of urea. In addition, samples of acid-treated urine from the sheep receiving the same ration as well as from the other three rations were dried and the energy and nitrogen contents determined. In some samples the carbon content of the dried product was also determined.

Some carbon is normally lost from urine to which acid has been added. In studying this problem Grose (1950) derived a factor for

correcting for the loss of carbon in the acidified urine of sheep receiving a ration of alfalfa hay. However, in the present experiment involving rations unlike alfalfa hay, it was considered desirable to determine this value experimentally. Two sheep were placed on each ration for a 10-day preliminary period, following which freshly voided urine samples were collected for 2 days and divided into two aliquots. One aliquot was made acid by adding 1:1 sulfuric acid until the pH value, as determined on a Beckman pH meter, corresponded with the previously

TABLE 3. COMPARISON OF MEAN DIGESTION COEFFICIENTS

Period and ration	Dry matter	Crude protein	Ether extract	Crude fiber	Nitrogen free extract	Digestible energy	TDN
	%	%	%	%	%	%	%
Period 1, Ration 1 Ammoniated condensed distillers molasses solubles	74.8	66.2	80.7	48.9	84.7	73.4	63.8
Period 2, Ration 2 Ammoniated cane molasses	75.2	63.7	76.9	49.5	86.0	73.5	64.9
Period 3, Ration 3 Urea ration	77.6	76.5	80.6	51.4	87.0	76.1	70.9
Period 4, Ration 4 Soybean oil meal	77.6	76.1	78.1	51.1	87.0	76.4	70.5
Least significant difference to give significance at the one percent level	2.0	5.1	2.6	3.7	1.6	2.4	1.6

determined average value of the five samples collected during the regular collection period. (The variation between the pH values of the sample of urine collected from sheep receiving the same ration was so small that no appreciable error was introduced by using an average pH value.) The acid aliquot was stored for 11 days and then analyzed for its carbon content. The other aliquot was analyzed immediately and correction made for the loss which occurred in the acidified sample.

The data were analyzed by the Method of Analysis of Variance as described by Snedecor (1946).

Results and Discussion

Table 3 representing the total of 220 sheep days, exhibits the mean digestibility coefficients of the feed constituents in the different rations

and the least significant difference to indicate a statistical significance at the one percent level.

In the digestion of dry matter, the two rations which contained the ammoniated products gave coefficients of digestibility lower than the other two rations. Although a statistical significance is indicated, the differences are small. The crude protein (N x 6.25) of the ration containing urea was digested practically equal to that of the ration containing soybean oil meal. The crude protein in both of these rations was digested better than the crude protein in ration 1 or ration 2.

There was no difference in the digestibility of the ether extract contained in rations 1 and 3. Both of these rations gave mean coefficients that were significantly different from that of ration 2. Since the feces ether extract contains products of metabolic origin, the determination of apparent digestibility of this constituent is always subject to error.

There was no significant difference in the digestion of crude fiber from the different rations. The digestion of the nitrogen-free extract in rations 3 and 4 was the same with both of these rations being significantly better digested than that from the ration containing the ammoniated CDMS. The effect of the level of nitrogen-free extract on its digestibility is well known (Swift *et al.* 1947). It is emphasized that the nitrogen-free extract level of these rations was nearly equal. This is true because cerelose was added to rations 3 and 4.

The digestibility of the energy contained in the rations followed the same trend as the digestibility of dry matter. The Total Digestible Nutrient (TDN) content also follows this trend, however, the spread between the different rations is much greater than in the case of energy. The reason for this is not clear but it is pointed out that digestible energy is obtained from two direct and accurate analyses; whereas the TDN content is the sum of the digestible ether extract (multiplied by 2.25), digestible protein, digestible fiber and digestible nitrogen-free extract. As a result, it contains all the errors involved in the determination of the individual components making up the TDN content of a ration.

Table 4 presents a summary of the balances of nitrogen, carbon, and energy and the calculated heat production values. In the case of ration 1, the directly determined heat production value is also given.

It is of interest that the urea, which contains no preformed protein, when compared to soybean oil meal as a source of nitrogen under almost identical conditions promoted a slightly greater storage of nitrogen in the body. It is also of further interest to note that the ration containing

ammoniated cane molasses promoted a greater storage of nitrogen than did the ammoniated CDMS, (the latter ingredient also contained some preformed protein i.e.—dead yeast and other organisms remaining after the fermentation process was completed). Considered in this light, these

TABLE 4. BALANCES OF CARBON, ENERGY AND NITROGEN PER SHEEP PER DAY

Item		Ration 1 Ammoniated CDMS	Ration 2 Ammoniated cane molasses	Ration 3 Urea	Ration 4 Soybean
Nitrogen					
Intake	gm.	15.12	15.05	15.65	15.57
Feces	gm.	5.11	5.37	3.62	3.75
Urine	gm.	8.35	7.65	8.45	8.68
Balance	gm.	1.66	2.03	3.48	3.14
Carbon					
Intake	gm.	337.1	325.7	324.70	338.2
Feces	gm.	89.5	86.8	76.6	78.4
Urine	gm.	14.8	15.2	12.4	14.5
Methane	gm.	16.4	14.8	16.8	17.6
CO_2	gm.	183.8	179.3	196.0	190.9
Balance	gm.	32.6	29.7	22.9	36.8
Energy					
Intake	Cal.	3341	3270	3260	3341
Feces	Cal.	885	863	765	792
Urine	Cal.	120	160	106	123
CH_4	Cal.	292	264	299	313
Metabolizable energy	Cal.	2044	1983	2090	2113
Metabolizable energy/kg. dry matter	Cal.	2660	2648	2784	2795
Heat production*	Cal.	1771	1653	1792	1578
Heat production by direct calorimetry*	Cal.	1750	—	—	—
Live Weight	lbs.	77.0	83.0	87.0	92.0

*Corrected to 85 pounds live weight in accord with 0.73 power of the live weight.

data may indicate that the rumen microorganisms can utilize the simpler nitrogenous compounds better than they utilize preformed protein. This, however, does not explain why the ammoniated products gave inferior results when compared to rations 3 or 4. The work of Thomas *et al.*, (1951) showing that sulfur in the inorganic form is utilized

by the rumen microorganisms, may have value in interpreting the results obtained here. No additional sulfur was added to any of these rations. Sulfur analysis, by the magnesium nitrate method (A. O. A. C., p. 104, 1950) reveals that rations 1, 2, 3 and 4 contained 2.60, 1.37, 1.00 and 1.03 grams of sulfur per kilogram of ration, respectively. As the rations containing the least amounts of sulfur promoted the highest storage of nitrogen, a lower percentage of this element does not explain the lower storage of nitrogen by the rations containing the ammoniated products. Perhaps sulfur in an organic combination would have improved these rations. Loosli and Harris (1945) found methionine to increase greatly the storage of nitrogen by sheep receiving urea-containing rations. Sodium sulfate under similar conditions did not greatly improve the urea-containing rations.

In the carbon-nitrogen balance method, heat production was calculated by subtracting the calories stored as protein and fat from the metabolizable energy content of the ration. Ration 4 promoted a higher storage of total carbon than did the rations containing the ammoniated products, while the urea-containing ration gave a much lower storage. The heat production values were 1771, 1653, 1792 and 1578 Calories per day for rations 1, 2, 3 and 4, respectively. These values were corrected to a standard weight of 85 pounds in accord with 0.73 power of the live weight. The average weight of the four groups of sheep was 84.8 pounds. It is of interest to note that the urea-containing ration had a high metabolizable energy value. Since the utilization of metabolizable energy approaches constancy in balanced rations, (Kriss, 1943) these data might indicate that ration 3 was in some way unbalanced. As the CO_2 production of the group of sheep receiving the urea-containing ration was somewhat higher than that of the sheep receiving the other rations, the factor of activity of the sheep may have been operative although no definite evidence of this was observed.

In the study of the loss of carbon from urine upon acidification it was found that the percentage losses were 3.60, 8.89, 2.78 and 4.98 for rations 1, 2, 3 and 4, respectively. All of these values are below the 11.00 percent loss found by Grose (1950). The carbon content of the urine samples dried at a low temperature (60° C.) compared favorably with the carbon content of the acid urine. Also the energy content of the dried acid-treated urine agreed closely with the energy content of the urine which was dried with no preservative. A 10 percent error in the energy value of the urine would correspond to about one-half of one percent of the gross energy intake.

A test was made to determine the loss of nitrogen from rations containing ammoniated products and urea during a storage period of 120 days. It was found that no loss of nitrogen occurred.

The results of the feeding trial are exhibited in table 5 and show that these feeds are acceptable for long periods of time at the higher levels of intake found here. The excellent gains obtained may be due, in part, to the condition of the sheep when placed on feed. These

TABLE 5. INTAKE AND EFFICIENCY OF THE 32-DAY ACCEPTABILITY TRIAL

Item	Ammoniated CDMS ration		Ammoniated cane molasses ration	
Sheep number	2	9	4	11
Initial weight (lbs.)	85.0	98.0	94.0	90.0
Final weight (lbs.)	102.0	117.0	115.0	104.0
Total gain in weight (lbs.)	17.0	19.0	21.0	14.0
Average daily gain (lbs.)	0.53	0.59	0.66	0.44
Feed Consumption:				
Concentrate lbs.	114.9	104.3	117.5	88.4
Hay lbs.	5.2	5.5	5.6	4.9
Protein* lbs.	20.14	18.72	21.13	15.70
Energy* Therms	206.86	189.45	215.81	163.22
Feed Efficiency:				
Lbs. protein/lb. gain	1.18	0.99	1.01	1.12
Therms/lb. gain	12.17	9.97	10.28	11.66
Lbs. concentrate/lb. gain	6.8	5.5	5.6	6.3
Lbs. hay/lb. gain	.3	.3	.3	.4

* The protein and energy analyses were 15.04 and 3777; 15.36 and 3835; 5.50 and 4289 percent and calories per gram, respectively, for the ammoniated CDMS ration, ammoniated cane molasses ration, and the timothy hay.

animals had been on restricted feed intake for approximately sixty days just prior to the time that they were placed on this experiment.

Summary

When ammoniated condensed distillers molasses solubles, ammoniated cane molasses and urea (262) were mixed with cerelose and a basal mixture composed of natural feedstuffs in such a way that the total rations were iso-caloric and iso-nitrogenous and compared to soybean oil meal fed the same way to growing sheep, the following results were obtained:

1. The ration constituents of the urea-containing ration were digested as well as those of the soybean oil meal-containing ration.

2. The addition of the ammoniated products decreased the digestibility of all ration constituents except ether extract. The differences in all constituents except crude fiber and NFE were statistically significant, but were small except in the case of crude protein.

3. The sheep receiving the urea ration stored slightly more nitrogen than the sheep receiving the soybean oil meal ration. Both of these rations were superior in this respect to both of the rations containing the ammoniated products.

4. The soybean oil meal ration contained the highest level of metabolizable energy and was followed in order by the urea, ammoniated CDMS and ammoniated cane molasses rations. There was a spread of only 6.2 percent between the highest and lowest values.

5. In the storage of total carbon and body fat, the urea ration was definitely inferior to all the rations used in this study.

6. There was no loss of nitrogen from the rations containing urea or either of the ammoniated products when they were stored in open containers at room temperature for a period of 120 days.

7. The results of the palatability trial indicate that both ammoniated products are palatable to sheep when fed at the level of ten percent by weight of the total ration.

8. There was good agreement between the directly determined and calculated heat production values.

Literature Cited

Arias, C., W. Burroughs, P. Gerlaugh and R. M. Bethke. 1951. The influence of different amounts and sources of energy upon in vitro urea utilization by rumen microorganisms. JOURNAL OF ANIMAL SCIENCE 10:682.

Association of Official Agricultural Chemists. 1950. Official and tentative methods of analysis. 7th edition. Association of Official Agricultural Chemists, Washington, D. C.

Bratzler, J. W. 1951. A metabolism crate for use with sheep. JOURNAL OF ANIMAL SCIENCE 10:592.

Burroughs, W., A. Latona, P. DePaul, P. Gerlaugh and R. M. Bethke. 1951. Mineral influences upon urea utilization and cellulose digestion by rumen microorganisms using the artificial rumen technique. JOURNAL OF ANIMAL SCIENCE 10:693.

Culbertson, C. C., P. S. Shearer, W. E. Hammond and S. Moore. 1950. Protein substitutes with and without molasses for fattening yearling steers. Iowa State College Agr. Ext. Ser. A. H. 176.

Goss, H. 1943. Some peculiarities of ruminant nutrition. Nutr. Abs. and Revs. 12:531.

Grose, E. C. 1950. The effect of sulfuric acid treatment on the carbon content of sheep urine. Unpublished data, Department of Animal Nutrition, The Pennsylvania State College.

Hart, E. B., G. Bohstedt, H. J. Deobold and M. I. Wegner. 1939. The utilization of simple nitrogenous compounds such as urea and ammonium bicarbonate by growing calves. Jour. Dairy Sci. 22:785.

Knodt, C. B., J. B. Williams and J. Brumbaugh. 1951. Ammoniated cane molasses and similar products in the rations of dairy calves. Jour. Dairy Sci. 34:1042.

Krebs, K. 1937. Der Wert der Amide Bei der Futtering des Rindes. Biedermanns Zentralblatt Tierernahrung 9:394.

Kriss, M. 1943. Evaluation of feeds on the basis of net available nutrients. JOURNAL OF ANIMAL SCIENCE 2:63.

Loosli, J. K. and L. E. Harris. 1945. Methionine increases the value of urea for lambs. JOURNAL OF ANIMAL SCIENCE 4:435.

Loosli, J. K., H. H. Williams, W. E. Thomas, F. H. Ferris and L. A. Maynard. 1950. Synthesis of amino acids in the rumen. Science 110:144.

McNaught, M. L. and J. A. B. Smith. 1947. Nitrogen metabolism in rumen nutrition. Nutr. Abs. and Revs. 17:18.

Magruder, N. M., C. B. Knodt and P. S. Williams. 1951. The value of ammoniated industrial by-products in the rations of dairy heifers and cows. JOURNAL OF ANIMAL SCIENCE 10:1055.

Millar, H. C. 1941. Preparation of ammoniated sugar beet pulp and corn silage. Use of protein food for ruminant. Ind. and Eng. Chem. 33:274.

Millar, H. C. 1942a. Ammoniated agricultural materials as livestock feed and process for producing same. U. S. Patent 2 293 845.

Millar, H. C. 1942b. The pilot plant ammoniation of dried sugar beet pulps. Proc. Soc. Am. Sugar Beet Tech.

Millar, H. C. 1944. Ammoniated sugar beet pulp as a nitrogenous feed for ruminants. Jour. Dairy Sci. 27:225.

Reid, J. T. 1951. The utilization of urea by ruminants. Proc. Cornell Nutrition Conference.

Snedecor, C. W. 1946. Statistical Methods. Iowa State College Press, Ames, Iowa.

Swift, R. W., E. J. Thacker, A. Black, J. W. Bratzler and W. H. James. 1947. Digestibility of rations for ruminants as affected by proportions of nutrients. JOURNAL OF ANIMAL SCIENCE 6:432.

Swift, R. W., J. W. Bratzler, W. H. James, A. D. Tillman and D. C. Meek. 1948. The effect of dietary fat on the utilization of the energy and protein of rations by sheep. JOURNAL OF ANIMAL SCIENCE 7:475.

Thomas, W. E., J. K. Loosli, H. H. Williams and L. A. Maynard. 1951. The utilization of inorganic sulfates and urea nitrogen by lambs. Jour. Nutr. 43:515.

Tillman, A. D. and J. F. Kidwell. 1951. The value of ammoniated condensed distillers molasses solubles as a feed for beef cattle. JOURNAL OF ANIMAL SCIENCE 10:934.

THE FECAL AND URINARY EXCRETION OF CERTAIN B VITAMINS BY SHEEP FED HAY AND SEMI-SYNTHETIC RATIONS[1]

P. B. Pearson, Lee Struglia, and Ivan L. Lindahl

U. S. Department of Agriculture

MICROORGANISMS are rather specific in their requirements for growth and it might be expected that the composition and physical properties of the ration will influence microbial activity in the rumen. Concentrates are not regurgitated to the same extent that roughage is and it seems likely that the time the concentrates remain in the rumen is somewhat shorter than is the case for roughage. It would appear then that on a high concentrate ration, rates of intestinal synthesis of the B vitamins and their breakdown might be different than on a roughage ration. Evidence has been presented (Teeri *et al.*, 1951) indicating that silage and possibly cane molasses favor rumen synthesis of riboflavin and thiamine whereas nicotinic acid synthesis was unaffected by the kind of roughage fed. Using the artificial rumen technique, Hunt, Bentley and Hershberger (1952) found that the addition of trace elements to the medium inoculated with rumen contents of steers fed a low protein ration resulted in an increase in several of the B vitamins. Their results also indicate that the addition of starch to the inoculum from steers fed low protein rations favors the synthesis of B vitamins.

The work reported here was undertaken to obtain information on the effect of the level of fiber, protein and a semi-synthetic diet as compared with a roughage ration on the intestinal synthesis of four B vitamins. Sheep were used as experimental animals as they are easily handled and the feces and urine can be collected quantitatively.

Experimental

The sheep used were mature wethers in good condition that had been treated for internal parasites. Either six animals were used on each dietary regimen or three animals and the trials repeated resulting in a total of six collections. The experimental rations were fed for at least two weeks before collections were made. Since the B vitamin values were not significantly different at subsequent collections, it may be assumed that the microbial activity had been established for the dietary regimen when the first collections were made. The collections were

[1] Bureau of Animal Industry, Beltsville, Maryland.

made over a period of three consecutive days. Fecal collection bags were used to avoid contamination of the feces with the urine. The feces were dried at 60° C. and ground for vitamin analysis. The urine was collected in amber glass bottles with toluene to prevent bacterial action and sufficient sulfuric acid to keep the pH below 6.5. Standard microbiological procedures were used for assaying for riboflavin, niacin, pantothenic acid and vitamin B_{12}.

Three semi-synthetic rations were used. Ration number 1 had the following percentage composition: dextrinized starch 15, corn 31.9, molasses 10, cerelose 16.9, casein 10, peanut oil 1.7, sodium chloride 1, dicalcium phosphate 1, vitamin A and D oil 0.5, wood pulp 7, and agar 5.0. This ration contained 12.6 percent protein and 6.8 percent fiber. Semi-synthetic ration number 2 was the same as number 1 except that one pound of urea as marketed for feeding purposes was added so that the protein equivalent of this ration was 15.2 percent. Semi-synthetic ration number 3 was the same as ration number 1 except that the casein was replaced by an equivalent amount of corn. This ration contained 3.6 percent protein. The mixed hays used in the experiment contained approximately 50 percent legumes and 50 percent grass. The mixed hay "ration 2" was the same as hay "ration 1" except that it contained one pound of urea per 100 pounds of hay. Hay ration 1 contained 13.6 percent protein and hay ration 2, 16.2 percent protein equivalent. The rations were all pelleted which avoided selection of components by the sheep.

Results and Discussion

The amounts of each of the B vitamins ingested by the sheep fed the semi-synthetic rations, while not identical, were of the same order of magnitude, thus the amounts excreted on the different dietary regimens can be compared. The amounts of the vitamins ingested on the hay rations were much higher than on the semi-synthetic rations. Consequently, the data do not lend themselves to comparisons between the hay and semi-synthetic treatments, except in the case of vitamin B_{12}. The amounts of the vitamins excreted in the feces may be assumed to reflect the combined effects of microbial synthesis, destruction in the gastro-intestinal tract, and metabolic processes.

Riboflavin

The amount of riboflavin excreted in the feces was not influenced significantly by the level of protein or the addition of urea to a semi-

synthetic ration. The 3-day excretion for the groups fed the semi-synthetic rations varied from 7.2 mg. to 8.1 mg. The sheep fed the mixed hay rations excreted substantially less riboflavin than they ingested indicating destruction in the gastro-intestinal tract. This is in accordance with the finding that only 1.7 to 23.3 percent of ingested synthetic riboflavin is recovered in the feces and urine of sheep (Olcese and Pearson, 1948). It appears that through microbial activity a riboflavin level designed to meet the organisms requirements is maintained in the gastro-intestinal tract of ruminants.

TABLE 1. EXCRETION OF RIBOFLAVIN, NIACIN AND PANTOTHENIC ACID BY SHEEP FED DIFFERENT RATIONS

(Values for three-day period)

Ration	Semi-synthetic 1	Semi-synthetic 2 urea	Semi-synthetic 3 low protein	Mixed hay 1	Mixed hay 2 urea
Riboflavin:					
intake, mg.	4.3	4.1	2.2	58.9	57.3
feces, mg.	8.1	7.2	7.2	16.5	18.6
urine, mg.	12.3	9.6	4.4	13.9	12.3
Niacin:					
intake, mg.	23.7	19.2	33.3	123.7	148.1
feces, mg.	17.3	17.9	18.7	47.3	54.2
urine, mg.	25.7	25.7	7.1	24.4	26.2
Pantothenic acid:					
intake, mg.	8.7	9.3	7.2	66.1	89.1
feces, mg.	3.6	3.5	4.7	9.2	12.9
urine, mg.	49.5	54.3	25.6	49.2	53.2

Niacin

The amount of niacin excreted in the feces was not significantly influenced by the level of protein or the addition of urea to the ration. The sheep fed the mixed hay ration excreted in the feces an average of 47.3 mg. niacin for the 3-day period as compared with 54.2 mg. for the group fed the mixed hay plus urea. This difference is not considered significant and is probably due to the higher intake of niacin by the sheep on the ration containing urea. The total excretion of niacin was less than the intake on both of the hay rations. The urinary excretion of niacin was definitely affected by the level of protein in the ration. The sheep fed the low protein semi-synthetic ration excreted for the 3-day period in the urine 7.1 mg. of niacin as compared with 25.7 mg.

for the sheep fed the ration containing 12.6 percent protein. This reflects the higher intake of tryptophan and its conversion to niacin which has previously been shown to occur in the sheep (Pearson, Perlzweig and Rosen, 1949). When the sheep fed the low protein ration were changed to semi-synthetic ration 1, the urinary excretion of niacin increased to 26.7 mg. for the 3-day period. Since the addition of urea to the semi-synthetic ration did not result in an increase in the urinary excretion of niacin, this indicates that under the particular conditions of this experiment the microbial synthesis of tryptophan was not significant.

Pantothenic acid

The urinary excretion of pantothenic acid by the sheep fed semi-synthetic rations 1 and 2 was approximately 14-fold greater than the fecal excretion. Less than 4 mg. were excreted in the feces as compared to about 50 mg. in the urine. This indicates that there is relatively efficient absorption of pantothenic acid. The total excretion on the semi-synthetic rations was from four to six times the intake. It is of significance that the group fed the low-protein semi-synthetic ration excreted in the urine 25.6 mg. as compared with 49.5 mg. and 54.3 mg. for semi-synthetic rations adequate in protein. This would suggest that on a low-protein ration the microbial synthesis is less efficient than on an adequate protein ration or that the actual requirements for pantothenic acid are higher on a low-protein ration resulting in lowered urinary excretion.

Vitamin B_{12}

The data for the intake and excretion of vitamin B_{12} by sheep on the various rations are shown in table 2. The amounts of vitamin B_{12} synthesized in the gastro-intestinal tract and excreted in the feces are very striking. The intake of vitamin B_{12} by the sheep on the semi-synthetic rations was between 3 and 5 mcg. for the 3-day period, whereas the fecal excretion exceeded 650 mcg. On the basis of the amounts excreted in the urine, which did not exceed 20 mcg. for any of the groups, it would appear that vitamin B_{12} is either poorly absorbed by the sheep or that it is metabolized to some other compounds. It has been shown, using cobalt^{60} labeled B_{12}, that the rat absorbs only a very small percentage of ingested B_{12} (Chow *et al.*, 1951). The synthesis of vitamin B_{12} when the hay ration was fed was in the order of three times more than when the semi-synthetic rations

were fed. This may reflect a change in the types of microorganisms due to the character of the ration or a direct effect on the activity of the organisms that synthesize vitamin B_{12}. The differences in the synthesis of vitamin B_{12} by the sheep on the semi-synthetic rations and the hay rations could not be accounted for on the basis of the cobalt contents of the rations as they were essentially the same as shown by spectrographic analysis.

Summary

The apparent synthesis of riboflavin as measured by urinary and fecal excretion by sheep was not essentially affected by feeding a low-protein ration or by adding urea to the ration. Feeding a low-protein ration to sheep reduced the urinary excretion of niacin to about one-third of the amount excreted by sheep fed a ration containing 12.6 percent protein. This is probably due to the lower intake of tryptophan which can be converted to niacin by sheep. The total excretion of pantothenic acid exceeded by four to 6-fold the amount ingested when semi-synthetic rations were fed. Sheep fed a semi-synthetic ration adequate in protein excreted over 93 percent of the pantothenic acid in the urine and less than 7 percent in the feces. Sheep fed a low-protein ration excreted in the urine significantly less pantothenic acid than sheep fed a ration adequate in protein.

Relatively large amounts of vitamin B_{12} are synthesized in the gastrointestinal tract of sheep. The ratio of B_{12} ingested to the amount excreted in the feces by the sheep fed the semi-synthetic rations was in the order of 120 to 210. The microbial synthesis of B_{12} when a mixed hay ration was fed exceeded by about three times the synthesis when

TABLE 2. EXCRETION OF VITAMIN B_{12} BY SHEEP FED DIFFERENT RATIONS

(Values for three-day period)

Ration	Intake	Urinary excretion	Fecal excretion	Apparent synthesis[1]
	mcg.	mcg.	mcg.	mcg.
Semi-synthetic 1	3.2	4.2	678.0	679.0
Semi-synthetic 2	5.0	12.6	880.0	887.6
Semi-synthetic 3	5.1	5.3	606.4	606.6
Mixed hay 1	83.1	13.4	2,120.4	2,050.7
Mixed hay 2	34.5	17.8	3,262.8	3,246.1

[1] Apparent synthesis=Urinary excretion plus fecal excretion minus amount ingested.

a semi-synthetic ration was fed. Approximately 99 percent of the excreted B_{12} was found in the feces.

Literature Cited

Chow, B. F., C. Rosenblum, R. H. Silber, D. T. Woodbury, R. Ramamoto, and C. A. Lang. 1951. Oral administration of vitamin B_{12} containing cobalt^{60} to rats. Proc. Soc. Exp. Biol. Med. 76:393.

Hunt, C. H., O. G. Bentley and T. Hershberger. 1952. Factors affecting the synthesis of certain members of the vitamin B-complex in the artificial rumen. Feder. Proc. 11:233.

Olcese, O., and P. B. Pearson. 1948. The destruction in the gastro-intestinal tract of orally ingested riboflavin and pantothenic acid. Revue Internat. Vitamin. 20:128.

Pearson, P. B., W. A. Perlzweig and F. Rosen. 1949. The metabolism of niacin in ruminants. Arch. Biochem. 22:191.

Teeri, A. E., D. Josselyn, N. F. Colovos and H. A. Keener. 1951. Influence of the ration on the excretion of certain vitamins by ruminants. Jour. Dairy Sci. 24:1070.

THE USE OF SALT AS A REGULATOR OF PROTEIN SUPPLEMENT INTAKE BY BREEDING EWES

W. C. Weir and R. F. Miller, Jr.[1]

University of California[2, 3]

THE use of protein concentrates to supplement dry and leached native range feed has long been recognized as a desirable practice by livestock men. Recently many have expressed an interest in the use of salt to regulate the intake of such supplements, thereby making it possible to offer the mixture to the livestock in a self-feeder.

The use of such salt mixtures for cattle has been investigated by several workers—Pistor *et al.* 1950, Cardon *et al.* 1951, Savage 1950, Riggs *et al.* 1951, and Nelson *et al.* 1951. Little information is available on the salt tolerance of sheep. Bolin (1949) reported that lambs receiving a salt drench at the rate of 2.1 grams per pound of body weight died within 24 hours. Lundin and Scharf (1925) investigated the salt and water retention of sheep fed large quantities of salt. A normal, a pregnant, and a partially nephrectomized sheep were fed up to 100 grams of salt per day. The intact animals suffered no permanent damage, but the nephrectomized animal died when the salt intake was increased from 50 to 100 grams per day. Schmidt (1950) and Boughton (1950) of the Texas Station cite field observations of "salt poisoning" when sheep have been fed mixtures of salt and cottonseed meal for prolonged periods. On the other hand, Miller (1948) states "when water is good and convenient, sheep will apparently not consume enough salt to poison themselves" and further indicates that mixtures of cottonseed meal and salt are widely used. Cardon (1951) cites a reference in the 1946 Grazier's Annual of Australia that "salt fodders" such as linseed meal 40 percent, crushed grain 40 percent and salt 20 percent had been used successfully for sheep in Australia.

This paper presents the results of a test comparing the performance of pregnant and lactating ewes which were hand-fed cottonseed meal as compared to ewes which were fed the same amount of cottonseed meal mixed with salt.

[1] Now Farm Advisor, Tulare County, California.

[2] Department of Animal Husbandry, Davis.

[3] The authors express their appreciation to Dr. D. R. Cordy, Veterinary Science, for pathological examinations, and to J. G. Brown, Pomology, and L. W. Holm, Veterinary Science for the use of the flame photometer.

Experimental

As field results in California have shown that about ¼ pound of cottonseed meal per head daily is a satisfactory supplement for sheep on dry range feed, a preliminary test was set up to determine the percentage of salt necessary in a salt-cottonseed mixture to hold the consumption at this level. Five aged, open Merino ewes were placed on a basal ration of ¾ pound of alfalfa hay and barley straw *ad libitum*. For the first week, the ewes were hand-fed ¼ pound of cottonseed meal per head daily; the following week 10 percent salt was added to the cottonseed meal, the next week 20 percent, and finally 30 percent salt. When 30 percent salt was mixed with the cottonseed meal, some of the mixture was refused. The mixture was then changed to 25 percent salt and 75 percent cottonseed meal. The ewes did not consume quite all of this mixture. After a month on this ration, the ewes appeared thrifty and healthy, so a long-term test was organized.

Eighteen aged, bred, finewool ewes were allotted to 2 groups. Group I was fed a basal ration of ¾ pound of alfalfa hay and barley straw free-choice. A 25 percent salt-75 percent cottonseed meal mixture was self-fed. Group II was fed the same basal ration and hand-fed cottonseed meal. The quantity of meal fed Group II was determined by the amount Group I had received the previous 15-day period from the salt-cottonseed meal mixture. Both groups were kept in an open shed with adjacent exercise lot. Both groups had free access to water, consumption being measured throughout the test. Group II had free access to block salt at all times.

The ewes had been bred during the 6 weeks prior to the beginning of the trial. It was considered desirable to use pregnant ewes, as Lundin and Scharf (1925) had found a larger salt and water retention in a pregnant ewe than in a normal sheep. During the preliminary period both groups received alfalfa hay and ⅛ pound of cottonseed meal per head. Blood samples were collected during this period and analyzed for plasma sodium, potassium and chloride content.

The ewes were fed the experimental rations from November 4, 1950, until March 31, 1951—a total of 148 days. Fifteen of the 18 ewes lambed during the period from February 14 to March 27. All the ewes except one lambed before March 6. The ewes were weighed monthly until lambing started and at the close of the test. The lambs were weighed at birth, 14 days, and 28 days of age.

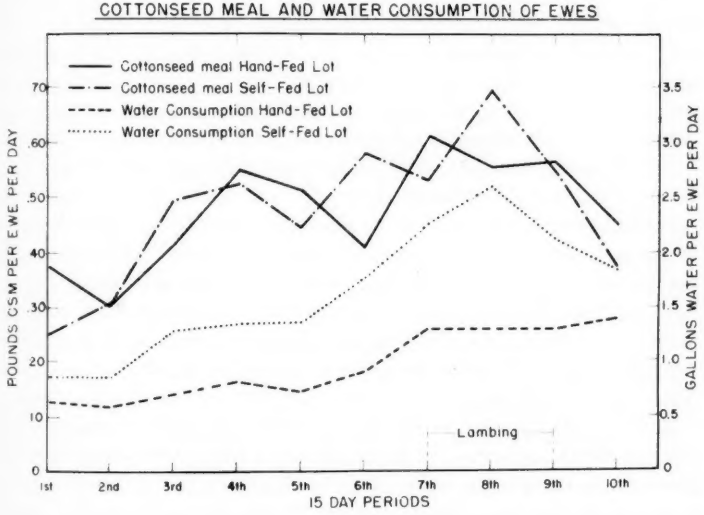
Blood and milk samples were analyzed for chloride by the method of

Van Slyke *et al.* (1923) as described by Reiner (1941) and for sodium and potassium using a flame photometer.

Results and Discussion

The cottonseed meal and water consumed by the ewes are shown in figure 1. The consumption of the salt-cottonseed meal mixture increased throughout pregnancy and decreased after lambing. The increase in water consumption of the salt-fed lot parallels the increased salt con-

Figure 1.



sumption. This increased water intake is in agreement with the findings of Lundin and Scharf (1925). The gradual increase in the water consumption of the control lot is probably a reflection of the increased demand during gestation and lactation, as no particularly warm weather was encountered during the course of the experiment. The salt intake (one-third the meal intake) ranged from 0.085 to 0.231 pounds per ewe per day.

The weights of the ewes during the trial are shown in table 1. Prior to lambing, the salt-fed group gained an average of 11 pounds, while the hand-fed group only gained 1 pound. This difference is not significant

TABLE 1. AVERAGE EWE BODY WEIGHTS DURING TRIAL
(Pounds)

Date:	11/3	12/5	1/6	2/5	3/26	4/1
Group I, Self-fed:	124.7	125.0	125.6	135.7	(7.0)[1]	95.5
Group II, Hand-fed:	128.3	121.0	124.3	129.8	(7.9)[1]	98.4

[1] Wool weight.

as there was much variation in weight change between individuals in both groups. Although this weight gain is less than is desirable during pregnancy, the ewes in both groups appeared healthy and thrifty throughout pregnancy. After lambing, the ewes which were nursing lambs became quite thin. The final average weight of each lot was approximately 30 pounds less than the beginning weight. An increased basal ration for the ewes after lambing was considered, but it was believed best to leave the basal ration constant to force the ewes to consume as much salt as they might under undesirable range conditions.

The lambing record and lamb weights are shown in table 2. One ewe in the salt group developed pregnancy paralysis. Two lambs were delivered from her by Caesarian operation. The lambs died but the ewe was saved, and after a two-week recovery period, she was placed back on the experiment. A second ewe in the salt group produced twins, both of which died within the first 24 hours. A third ewe in this group produced a single lamb which died of starvation at 21 days of age. On the other hand, three of these ewes raised twins which grew well considering the ration the ewes were receiving. In the hand-fed group, only three sets of twins were born. One lamb was stillborn, and one of each of the other pairs died within 24 hours after birth. These results indicate that there was no appreciable difference in the lambing performance of the two groups of ewes. It does demonstrate that ewes

TABLE 2. LAMBING RECORD

	Group I self-fed salt	Group II hand-fed
Number of ewes bred	9	9
Number of ewes lambed	8	7
Number of lambs born	13	10
Number of lambs alive at 28 days	8	7
Percent of lambs alive at 28 days	62	70
Pairs of twins at 28 days	3	0
Average weight of singles at 28 days	23	22
Average weight of twins at 28 days	18.5	0

TABLE 3. THE MEAN CHLORIDE, SODIUM AND POTASSIUM CONTENT OF THE BLOOD PLASMA OF EWES

(mgs./100 cc.)

Group	Number of ewes	Dates of bleedings			
		10/23	12/26	1/31	4/1
		Chloride			
I Salt	9	370	366	349*	311
II Hand-fed	9	369	357	338	307
		Sodium			
I Salt	9	289	280	297	347
II Hand-fed	9	296	274	306	343
		Potassium			
I Salt	9	33	27	23	23
II Hand-fed	9	29	25	22	22

* P=.05 for comparison with hand-fed group.

receiving a salt-cottonseed meal mixture are capable of rearing twin lambs.

The blood data on the ewes is shown in table 3. The blood chloride level of the high salt group was significantly higher than the level found in the control group at only one bleeding. During this period the average salt consumption per ewe was almost 0.2 pounds per day. The differences in the blood sodium and potassium levels were not significant. A hematocrit (packed cell volume) was determined on the blood samples drawn on January 31. The average value for the salt group was 40 percent cells as compared to 41 percent for the control group.

The milk from five ewes in each group was analyzed twice for chloride, sodium and potassium. The values obtained are shown in table 4. At both milkings the chloride and potassium content was sig-

TABLE 4. THE MEAN CHLORIDE, SODIUM AND POTASSIUM CONTENT OF EWES MILK

(mgs./100 cc.)

Group	Number of ewes	Chloride		Sodium		Potassium	
		March 24	March 30	March 24	March 30	March 24	March 30
I (Salt)	5	98.0*	102.0*	.321	.394	14.14*	13.50*
II (Hand-fed)	5	88.0	88.3	.325	.387	11.90	11.87

* P=.05 for comparison with control group.

nificantly higher for the milk of the ewes receiving the high salt diet while there was no difference in the sodium content.

The death of one ewe in the self-fed group late in the experiment and the death of lambs in both groups could not be attributed to treatment effects.

Two dry ewes from each group were maintained on the respective rations until May 9 or a total of 188 days from the beginning of the trial. These ewes were then killed and examined closely by a veterinary pathologist. No differences were found in adrenal gland or kidney weights. No differences were noted in these organs either by macroscopic or histological examinations.

The results of this trial indicate that sheep may be self-fed a mixture of 25 percent salt and 75 percent cottonseed meal without encountering "salt poisoning". The increased water consumption on the high salt ration indicates that water should be readily available to sheep fed in this way. A further test under actual range conditions (Weir and Torell, 1952) confirms this finding. Further studies are needed to determine the long-term effect of a large salt intake.

Summary

Two groups of breeding ewes were carried through gestation and lactation on a straw and limited alfalfa hay ration with a supplement of 25 percent salt and 75 percent cottonseed meal mixture self-fed to one group and an equal amount of cottonseed meal hand-fed to the other group. The ewes slowly gained weight through gestation but lost weight rapidly after lambing. There was no difference between the two groups' lambing performance or in the gains of the lambs to 28 days of age. The water intake of the ewes on the high-salt ration was much greater than that of the control ewes. Blood chloride level was increased only during the period of greatest salt intake. No effect was noted on the blood sodium or potassium levels or on the hematocrit value. The chloride and potassium content of the milk was higher for the ewes on the salt intake while no effect was found on the milk sodium. No evidence of "salt poisoning" was obtained.

Literature Cited

Bolin, F. M. 1949. Salt poisoning in sheep and swine. North Dakota Agr. Exp. Sta. Bi-monthly Bul. XI: 127–128.

Boughton, I. B. 1950. Personal communication.

Cardon, B. P., E. B. Stanley, W. J. Pistor and J. C. Nesbitt. 1951. Salt as a regulator of supplemental feed intake for range cattle. Proc. Western Sect. Am. Soc. Anim. Prod. Volume II.

Lundin, Harry, and Rudolph Scharf. 1925. The action of sodium chloride on normal, pregnant and partially nephrectomized animals. Jour. Metabolic Res. 7–8: 259.

Miller, J. C. 1948. Personal communication.

Nelson, A. B., R. W. MacVicar, W. J. Van Arsdell, and A. E. Darlow. 1951. Salt as a means of regulating consumption of cottonseed meal by beef cattle. JOURNAL OF ANIMAL SCIENCE 10:1058 (Abstract).

Pistor, W. J., J. C. Nesbitt and B. P. Cardon. 1950. The influence of high salt intake on the physiology of ruminants. Proc. Am. Vet. Med. Assoc. 154.

Reiner, M. 1941. Manual of clinical chemistry. Interscience Publishers Inc., New York.

Riggs, J. K., R. W. Colby and H. A. Smith. 1951. Effect of self-feeding salt-cottonseed meal mixtures to beef breeding cows. JOURNAL OF ANIMAL SCIENCE 10:1060 (Abstract).

Savage, D. A. 1950. Self-feeding of salt-meal mixtures to range cattle. Progress Report U.S.D.A. Southern Great Plains Field Station, Woodward, Oklahoma.

Schmidt, H. 1950. Personal communication.

Van Slyke, D. D. 1923. The determination of chlorides in blood and tissues. Jour. Biol. Chem. 58:523.

Weir, W. C. and D. T. Torell. 1952. Unpublished data. Calif. Agr. Exper. Sta.

RECORD OF THE PROCEEDINGS OF THE FORTY-FOURTH ANNUAL MEETING OF THE AMERICAN SOCIETY OF ANIMAL PRODUCTION

The forty-fourth annual meeting of the American Society of Animal Production was held in the Hotel Sherman in Chicago on November 28 and 29, 1952, and a dinner for the honor guest was held at the Stockyard Inn on November 30. Abstracts of most of the papers presented were published in the November, 1952 issue of the JOURNAL OF ANIMAL SCIENCE, Volume 11, pages 736–806.

PRESIDENT'S REMARKS AT OPENING SESSION

H. M. BRIGGS

President, American Society of Animal Production

Livestock production has been undergoing changes. Formerly it was considered an art and then science began to play an increasingly important role until it dominates the activities of our most successful producers. As science has played an increasing role in the production of meat, milk, wool and eggs, the research worker has been called upon to supply more and more facts for use by farmers, ranchers and processors.

The day is past when the scientists, especially those connected with our agricultural experiment stations, can neglect their duty of passing on their findings in the most useful and understandable manner to the public. When we tell and show the public how to use our research findings, then, and only then, have we completed our job. Today we have many new and improved media for "Telling our Story", and it is a part of our job to see that they are effectively used. In the laboratory and experimental pen we use the best equipment and technique available, and tools of the same quality must be used in passing information to the producer and consumer.

A SUMMARY OF THE MINUTES OF THE FORTY-FOURTH BUSINESS MEETING OF THE AMERICAN SOCIETY OF ANIMAL PRODUCTION

J. I. MILLER, *Secretary*
Cornell University

The meeting was called to order in the Louis XVI Room of the Hotel Sherman, Chicago, at 2:30 p.m. by President Briggs. The minutes of the 1951 business meeting were not read as they had been published in the JOURNAL OF ANIMAL SCIENCE Volume 11(1):198–205. It was moved and seconded that they be approved as published and the motion carried.

The secretary reported that membership in the Society consisted of 1176 domestic and 64 foreign with a total of 1240 members. There was a gain of 33 domestic and 6 foreign members in comparison with 1951. Subscriptions to the JOURNAL OF ANIMAL SCIENCE received in 1952 totaled 805; or 166 more than in 1951.

During the fiscal year, the secretary had sent three letters to the entire membership in addition to a large amount of correspondence necessary to members and subscribers in the conduct of business concerning the JOURNAL OF ANIMAL SCIENCE. An estimated total of at least 4,500 items of correspondence had been sent.

The treasurer's report showed that income during the year to the Morrison Award Fund amounted to $1,521.25. Expenditures amounted to $1,137.64. The balance on hand in this fund on November 1, 1952 was $2,047.78.

The income to the General Fund of the Society for the fiscal year (November 1, 1951–October 31, 1952) amounted to $21,390.83. The expenditures during the year totaled $16,746.69, which left an operating gain of $4,644.14 for the fiscal year. This gain somewhat more than compensated for the operating loss of $3,252.26 incurred in the previous fiscal year. The cash balance on hand in the General Fund at the close of the year was $5,920.69. In addition, the Society has assets of $4,550 in U.S. Bonds, Series F, and $7,000 in U.S. Bonds, Series G.

The Auditing Committee, consisting of R. M. Bethke, L. E. Hanson, and C. F. Sierk, reported the treasurer's books in satisfactory order and in accord with the treasurer's report to the Society.

The editor of the JOURNAL OF ANIMAL SCIENCE, L. E. Casida, gave the following report:

"A total of 806 papers has been considered for publication in the JOURNAL OF ANIMAL SCIENCE from its beginning 11 years ago through November 15, 1952. Of these, 671 have been published.

"Publication during 1952 (Volume 11) included 80 papers, the president's address and other Society proceedings of the 1951 meeting (including memorials, awards, and committee and program chairmen for 1952), 164 abstracts of papers presented at the 1952 annual meeting of the Society, subject and author indexes of Volume 11, and the usual News and Notes Section in each of the four issues of the JOURNAL.

"Manuscripts received during the period from November 16, 1951 to November 15, 1952, totaled 100. Of these 9 have been withdrawn or rejected, 45 have been published, 26 are in press to appear in the February 1953 issue, 16 are being revised by the authors and 4 are being reviewed by the Editorial Board.

"A maximum of 71 acceptable papers became available for publication during the past year and at the same time 80 papers have been published in Volume 11 of the JOURNAL. All papers on which editorial work had been completed at the time were sent to press for each of the four issues.

"Note should be taken of the fact that a peak in number of manuscripts submitted was reached at 122 in 1950. There has been a decline to 116 in 1951 and further to 100 in 1952.

"The Editor wishes to announce that the terms of E. W. Crampton and L. E. Kunkle on the Editorial Board will expire on December 31, 1952. The Executive Committee has appointed W. M. Beeson and R. W. Bray to replace them."

The records of the business manager of the JOURNAL OF ANIMAL SCIENCE listed the following back numbers of the JOURNAL available for sale:

Vol.	Year	Complete volumes	Number of copies in single issues			
			No. 1	No. 2	No. 3	No. 4
1	1942	0	0	7	16	36
2	1943	9	46	33	9	16
3–6	1944–47	0	0	0	0	0
7	1948	4	10	5	19	4
8	1949	0	0	0	14	12
9	1950	0	0	0	81	85
10	1951	0	9	97	0	78
11	1952	0	0	28	137	212

These back numbers may be purchased from the business manager at the following rates: Volumes 10 and 11, $1.75 per single copy for domestic and $2.00 for foreign; for preceding issues, $1.00 and $1.25, respectively. In addition, the following Proceedings of the American Society of Animal Production may be purchased at a cost of $1.00 each for domestic and $1.25 each for foreign:

1915–16	56	1930	23
1920	4	1931	65
1922	363	1932	22
1923	239	1934	43
1924	0	1935	41
1925–26	58	1937	0
1927	57	1938	0
1928	0	1939	13
1929	36	1940	65

The report of the Nominating Committee was given by W. G. Kammlade and was as published in the November, 1951, issue of the JOURNAL. No further nominations were made and M. L. Baker was declared elected as President. Ballots were distributed for voting on the election of Vice President.

President Briggs stated that the Committee on Investigations had submitted previously its report to the Executive Committee for study and possible action. He reviewed the contents of the report which follows:

"Possibilities were investigated of publishing the monograph without the use of the reserve funds of the Society. This would involve financing by a publishing concern or through some outside agency. Contacts were made with the National Research Council and several publishing concerns. Only one fairly definite proposal was received from the Scarecrow Press. They would publish the monograph at no cost to the Society and give a 10 percent royalty or possibly a 25 percent discount to members in lieu of a royalty. The cost would be about 2 cents per page. This proposal was referred to the Executive Committee.

"A proposal was made to the Committee by Dr. Burch H. Schneider of Washington State College regarding the micro-filming and distribution of Dr. Mitchell's references on nutrition. This matter would not obligate the Society in any way, but it opens up the question of adequacy of present facilities for making literature references available to research workers. This proposal was referred to the Executive Committee.

"Writing of the monograph is proceeding slowly. Two sections have been received by the Committee. The other authors have all done some work and it is believed that the writing is proceeding as fast as can be expected. It is hoped that all sections can be submitted to the Committee by April 1, 1953."

President Briggs reported that the Executive Committee had decided not to investigate further the publishing of the monograph by a commercial concern since the Society had voted last year to publish it. Also, he reported that the Executive Committee had voted to table the proposal regarding micro-filming and distribution of Dr. Mitchell's references on nutrition.

A. L. Anderson read the following report for the Committee on Instruction:

"The activities of this Committee centered mainly around the Teaching Section program for the Forty-Fourth Annual Meeting of the Society. The general plan of the program had been set by the group three years ago, it being the requirements for the various collegiate degrees. In previous years the Bachelor and Master of Science degrees were the subjects discussd. The subject this year was 'The Requirements for the Doctor of Philosophy Degree'. This was broken down into three fields: 1. Animal Breeding and Genetics; 2. Animal Nutrition; and 3. Animal Physiology. At a meeting of the Committee November 28, 1952, it was recommended that the papers presented at the 1952 Teaching Sections be published in the JOURNAL OF ANIMAL SCIENCE."

H. G. Zavoral, reporting for Extension, stated they had had an excellent program session, and had determined their committee for next year as follows: E. S. Matteson, Chairman; C. E. Bell, Jr., Vice Chairman; and H. G. Russell, secretary-treasurer.

The following report by the Committee on Information was read by H. H. Biggar:

"As usual this report must naturally deal with what results we have been able to secure relative to the use of news releases emanating from last year's Society program. Releases covering various news topics from this year's meeting have been released to the Chicago papers, and the press wire services including the Associated Press, United Press and International News Service—as well as to publications of the livestock and meat industry—cattle, sheep and hog papers, market papers, farm papers and publications of the meat trade. Regarding the livestock and meat industry publications, we find that 27 of them located in 16 states, used articles which measured a total of approximately 24 newspapers columns.

"Since we have asked our newspaper clipping bureau to be on the watch for such material, clippings have come in from daily and weekly papers. Some of these doubtless resulted from news releases sent out from the various colleges of agriculture. Others resulted from releases of our copy to the press wire services.

"These clippings have come from papers in 17 different states from Pennsylvania on the East to California. Taking account of duplications, stories concerning last year's meeting were used either in livestock industry papers or newspapers published in 23 different states."

E. F. Ferrin, Necrology Committee Chairman, presented the names of members who passed away during the year. Memorials are published in this issue of the JOURNAL. Members stood in silent respect.

H. H. Cole, special representative to the American Association for Advancement of Science Council reviewed briefly items of general interest to the Society. His report follows:

"The annual meeting of the A.A.A.S. Council was held in Philadelphia, Pennsylvania, December 27–29, 1951. Some of the more important actions at this meeting were:

1. Authorization of the Chairman of the Executive Committee to appoint an overall committee and subcommittees to study and analyze the various activi-

tives of the Association. Dr. Fred McKenzie, your representative last year, commented on this point at some length in his report.

2. The Council approved the affiliation of 11 and the association of 2 organizations.
3. A resolution was adopted which criticized the administrative procedures under the McCarran Act particularly as regards the prohibition of citizens going abroad and of citizens of other nations entering this country.
4. Plans for the meetings in St. Louis in Dec. 1952 and in Boston in Dec. 1953 were authorized by the administrative secretary. San Francisco has been tentatively selected for the 1954 Meeting and Chicago for the 1955 Meeting.
5. Reports of the following were made:
   Arden House Conference; Executive Committee; Publications Committee; Editorial Board; Committee on Affiliation and Association; Building Committee; Committee on the Revision of the Constitution and Bylaws; Cooperative Committee; Committee on the International Federation of Associations for the Advancement of Science."

H. W. Marston, representative to the Division of Biology and Agriculture, National Research Council, gave the following report:

"The Division of Biology and Agriculture set up a number of new committees during the past year. The first of these was a Committee on Plant and Crop Ecology. This committee was created in an effort to bring the plant sciences abreast with the animal sciences. Besides developing its long range objectives, this committee has taken action on certain practical measures of immediate bearing on problems of national security.

"A second committee was a Committee on Photobiology. This committee was set up to bring together the main areas concerned, including ultraviolet and infrared spectroscopy, physiology of vision, ultraviolet induction of cancer and mutations, photosynthesis, etc.

"A Committee on Animal Procurement was created which will help in devising systematic procedures for the breeding, rearing, certifying, registering and supplying of needed materials.

"A plan was adopted for creating a Committee Council, made up of six advisory committees with no operational functions, which between them would cover the whole field of the biological sciences and would be charged with keeping a running account of developments in the field of biology and making appropriate recommendations for its further development.

"The six published reports on Recommended Nutrient Allowances for Domestic Animals prepared by the Committee on Animal Nutrition have been well received during the past year. Four additional committee reports are nearing completion, namely, Recommended Nutrient Allowances for Dogs, Fur Bearers, and Rabbits and a report on the Use of Hormonal Materials in Animal Feeding.

"The Committee on Feed Composition is being reactivated to study effects of soil, climate, drying temperature, etc., on the nutritive value or availability of nutrients in animal feeds.

"The Committee on Laws, Rules and Regulations Governing Animal Health has submitted a compilation of State and Federal legislation for the control of animal diseases and those transmissible to man. The report is being prepared for publication.

"The first part of the Handbook of Biological Data, containing the quantitative data on blood, has been completed and printed in a publication for the Air Force. Work on a second part, dealing with nutrition and metabolism, is nearing completion, and work on a third, dealing with growth, reproduction and life histories, is well in progress.

"At the request of our President I attended the first meeting of the Agricultural Research Institute of the Agricultural Board of the National Research Council on October 16. Bylaws were adopted and the following officers were elected: Roy C. Newton, Swift & Co., President; Paul D. V. Manning, International Minerals & Chemical Corp., Vice President; and B. S. Clark, American Can Co., Secretary. A Board of Governors consisting of 17 Class A members and 10 Class B members was also elected.

"The purposes of the Agricultural Research Institute are:

(1) To promote the objectives of the Agricultural Board of the National Research Council; namely (a) to advance and interpret scientific knowledge pertaining to agriculture, (b) to initiate and provide recommendations relative to the science of agriculture based on objective analysis, and (c) to disseminate facts and conclusions by publication or otherwise among those agencies and population groups, including industry, where appropriate utilization and implementation can be effected. (2) To aid the Agricultural Board in the selection, initiation, and interpretation of the studies carried out by the Agricultural Board, particularly from the standpoint of their application to agriculture and industry. (3) To provide financial support to the Agricultural Board in order that its objectives can be carried out.

"Class A members of the Agricultural Research Institute will include corporations who are engaged in business involving agricultural products, or in scientific or economic research on projects related to agriculture. Class B members will include State and Federal experiment stations, academic institutions, scientific societies, and other associations and organizations who are engaged in agricultural activities and who are nominated by the National Research Council and elected by the Governing Board of the Institute.

"Class A members will pay annual dues of $300. Class B members are exempt from the payment of dues. At the initial meeting there were 32 Class A members present and 38 Class B members."

R. W. Phillips reported on the activities of the European Association of Animal Production as follows:

"The European Association of Animal Production was organized on the basis of membership of National associations rather than membership of individuals. The Association now has as members animal husbandry organizations in Austria, Belgium, Denmark, Finland, France, Germany, Iran, Israel, Italy, Luxembourg, French Morocco, the Netherlands, Spain, Switzerland, Tunisia, Turkey, the U.K. and Yugoslavia. Sixteen of these National organizations have been formally admitted to the Association. Of the other two, Turkey has indicated its adherence to the Association, but has not formally been voted in, while the U.K. has indicated that it would become a member through the joint action of two associations, the British Society of Animal Production and the Royal Agricultural Society of England. It will be noted that membership extends into non-European sections of the Mediterranean area, and that territories not having full National sovereignty are included

"The Association has a General Assembly which meets every three years, and the Second Assembly was held in Copenhagen, Denmark, at the time of the 6th International Congress of Animal Husbandry. This Congress was held from July 9–14, 1952, and was sponsored by the Association with the Government of Denmark acting as host. The General Assembly elects a Council, which is the governing body of the Association, and the terms of office members of the Council extend for 6 years, with a portion of the members being elected every 3 years.

"The funds for the Association are provided through membership fees of 3,500 Swiss francs per year for each of the National membership groups. Funds are spent primarily for the maintenance of a secretariat, the organization of meetings and the issuance of publications. Mr. K. de Kallay is Administrative Secretary and his office is at 54 Via Quintino Sella, Rome, Italy.

"I have mentioned one important difference between the European Association and the American Society of Animal Production—namely, the basis of membership. The method of handling meetings is also materially different. In the 6th International Congress of Animal Husbandry, for instance, the program was based primarily on invitation papers on a limited number of subjects: namely, (1) present viewpoints on breeding methods; (2) physiology concerning the vitamin B complex; (3) animal nutrition and fertility; (4) methods of calculating costs of animal production; and (5) advisory service in animal husbandry. Thus, it took the form of a series of symposia on selected subjects, in which invited speakers participated, rather than a meeting at which many of the members were free to present results of new research.

"The same applies to study meetings organized by the Association. Two such meetings were held in 1950, one dealing with the practical use of hormones in animal production, and the other with progeny testing in the breeding of farm animals. The proceedings of these study meetings have been issued in printed form by the Association.

"The general program of the Association for the next 3 years includes the organization of two study meetings, as follows: (1) present problems of meat production in Europe, to be held probably in September, 1953 in Italy; and (2) the influence of environment on animal production to be held in Switzerland in 1954.

"The program also includes the organization of the 7th International Congress of Animal Husbandry in 1956, probably in Spain. The Association will also collaborate with FAO and OEEC in a meeting on problems of animal feeding in Europe, which is tentatively scheduled to be held in Paris early in 1953, and it will give attention to the compilation of a dictionary of technical terms used in animal husbandry in English, French and German. The first draft has been prepared, and it is hoped that the document can be printed by the end of 1953.

"The Association has also six permanent study commissions, as follows: (1) Research; (2) Animal Nutrition; (3) Horse Breeding; (4) Cattle Breeding; (5) Sheep and Goat Breeding; and (6) Pig Production. The members of these Commissions carry out their work as a supplement to their regular activities at their home stations, and so function essentially as committees to bring together summaries of existing information and to stimulate research in certain fields.

"In conclusion, it may safely be stated that the European Association of Animal Production is now established on a firm footing, and that there is substantial and increasing interest in its work on the part of animal husbandry workers in Europe.

It is providing a useful means of interchange of information and ideas among workers in various countries, and should provide an excellent instrument for cooperation among countries, as its program of work develops."

The report of the Resolutions Committee, consisting of L. E. Johnson, Chairman, K. F. Warner and W. G. Kirk, was read and approved as follows:

"Your Committee recommends that the American Society of Animal Production express its appreciation to (1) the officers, (2) the editorial board, (3) the information and other committees for the useful and efficient way in which they have served the Society during the year.

"The Committee notes the continuation of the stimulating effect of (1) the Morrison Award and (2) the American Feed Manufacturer's Award and wishes to record again its gratitude to the donors.

"The special efforts of the Sherman Hotel to accommodate our expanding Society requires special mention and thanks this year."

President Briggs called for the consideration of the proposed amendment to the Constitution dealing with late and delinquent memberships. Secretary Miller read the proposed amendment which had been published in the JOURNAL, Volume 11(3):605. Upon vote, the amendment passed.

President Briggs brought up the matter of possible changes in scheduling and type of programs for the meetings next year. Various suggested changes had been offered to the Executive Committee for consideration and this committee in turn wished a general expression of opinion from the assembled group. The various changes discussed included time and place for the meetings, the substitution of three symposia sessions of technical nature in place of the opening session, whether more or fewer papers should be accepted for presentation, and the qualifications of a suitable paper. In general, the discussions and informal voting indicated the majority favored little or no change from the existing program arrangements.

President Briggs announced that the tellers had reported the election of A. E. Darlow for Vice President.

The meeting adjourned at 3:50 p.m.

MEMORIALS

HAROLD R. GUILBERT

Harold R. Guilbert was born December 5, 1897 in Columbus, Ohio, but his boyhood was spent with his parents on a ranch near Sharon Springs, Kansas. His education at Kansas State College, interrupted by service in World War I, was marked by the granting of a Bachelor's degree in 1920 and an M.S. in 1924. Between these dates he held the position of Instructor in Animal Husbandry at the College. He joined the staff of the University of California at Davis in 1924 with the rank of Junior Animal Husbandman and progressed to a Professorship in 1945.

Mr. Guilbert was married in 1920 to Frances Steele who was the mother of his two children. She passed away in 1937 and he married in 1940, Dr. Margaret Martin who at that time was the Dean of Women on the campus at Davis. She died in 1951.

Professor Guilbert contributed significantly to the data in the field of animal nutrition by his studies of the relation of nutrition to reproduction and of the minimum carotene and vitamin A requirements of animals. He was particularly interested in the mechanism of the growth of beef cattle and developed a plan for the numerical grading of cattle to assess their relative merits. He was also a strong advocate of plans for measuring the performance and for the progeny testing of beef cattle. Mr. Guilbert held several offices in the western branch of the Society of Animal Production—Secretary, 1939; Vice-president, 1940 and President, 1941. He was a member of Sigma Xi and the American Association for the Advancement of Science.

While in attendance at a meeting of the committee on animal nutrition of the National Research Council in Washington, D. C., Professor Guilbert suffered a heart attack and died October 16, 1952.

ROLAND JACOB KINZER

Roland Jacob Kinzer, one of the early members of this Society, was born in Marshall County, Iowa on December 12, 1876. In 1901, he received a B.S. degree with a major in Animal Husbandry from the Iowa State College. While a student he was known for his outstanding ability in the livestock field and was the highest ranking contestant in the judging contest at the 1901 "International." Mr. Kinzer was a member of the staff in Animal Husbandry at the Iowa State College from the time of his graduation until 1903 when he became a member of the faculty of Kansas State College. He made an unusual record at the latter institution serving as head of the Department of Animal Husbandry for several years and as coach of the livestock judging teams from 1904 to 1909. During the eight years of his employment at the Kansas State College, Mr. Kinzer became widely known as a judge of livestock at many major shows.

On January 1, 1911, Mr. Kinzer became Secretary of the American Hereford Cattle Breeders' Association and served very efficiently for a period of 33 years. During this time the Hereford breed made a phenomenal growth, registrations increasing from a few thousand head to nearly 300,000 cattle, yearly. Many honors and recognitions of outstanding service came to R. J. Kinzer during his term as

Secretary of the Association. His portrait was hung in the gallery of the Saddle and Sirloin Club at the Chicago Stock Yards, and the 1948 American Royal Hereford exhibit was designated the "R. J." show in his honor. Retiring from the position of Secretary in 1944, Mr. Kinzer was Chairman of the Board of the American Hereford Association until the time of his death from a cerebral hemorrhage, August 30, 1952.

E. J. WILFORD

E. J. Wilford was born at De Sota, Wisconsin on November 12, 1890 and died following a heart attack, January 4, 1952. He received a B.S. degree from Cornell University in 1917 and an M.S. from the University of Kentucky in 1925. With the exception of one year (1917) on a farm in New York State, the remaining years of his life were spent in college work. After a brief time as Instructor in Animal Husbandry at Purdue University he joined the staff of the University of Kentucky in 1918 and was promoted through the intervening ranks to a Professorship in 1939.

During the earlier years of his service at the University of Kentucky, Mr. Wilford specialized in swine work, conducting experiments upon the values of pastures, the effects of mineral components of rations and the feeding value of hybrid corn. Later, he turned his attention to meats and at the time of his death was in charge of the teaching and research in this field at the University of Kentucky. His studies of meats covered a considerable range, including methods for the home curing of pork and the body measurements of cattle as related to the dressing percent of the animals and the characteristics of the carcasses.

Professor Wilford is survived by his wife, Clara Crouch Wilford, two sons and four daughters.

JAMES J. LACEY

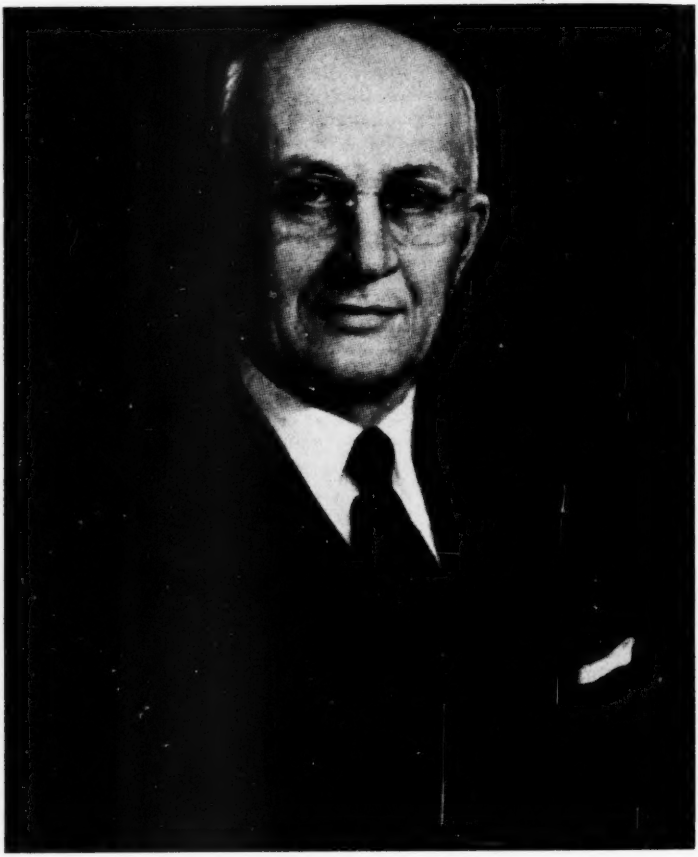
James J. Lacey was born May 8, 1888 in LaFayette County, Wisconsin and died at his home in Madison on June 3, 1952. He attended Marquette University for a time and received his Bachelor's degree from the University of Wisconsin. His first public position was in Green Lake County, Wisconsin, as emergency food agent from 1917 until 1919 and then as County Agricultural Agent until 1929. He became a member of the staff of the Animal Husbandry Department of the University of Wisconsin as Extension Animal Husbandman in 1929, specializing in sheep and swine work. One of his major projects was the demonstration of effective methods for the control of parasites of sheep and swine, a program which now has been adopted by most of the Wisconsin producers.

In order to improve the economic position of the farmers of Northern Wisconsin, Professor Lacey became an active advocate of increased numbers of farm flocks and of greater efficiency in sheep production. The control of predators of sheep was greatly improved by gaining the cooperation of the Wisconsin Conservation Department. He emphasized the importance of superior breeding and more adequate nutrition for the herds and flocks of the entire state. He was a convincing speaker, an effective and interesting writer and manifested enthusiasm and energy in all of his undertakings. His success as an extension worker was shown by the hearty

cooperation of thousands of the livestock farmers of the state of Wisconsin who were deeply affected by his demise.

Due to his wide acquaintance with farmers and stockmen in the state, Mr. Lacey served as a member of the Honorary Recognition Committee of the College of Agriculture for a period of more than ten years and as chairman during the last five years of his life. He was a member of the honorary extension fraternity, Epsilon Sigma Phi, and the Knights of Columbus.

In June, 1919, Mr. Lacey and Miss Dorothy Young were married. They raised a family of two sons and two daughters who with his widow survive him.



ARTHUR D. WEBER

Reproduction of a portrait presented to the Saddle and Sirloin Club in Chicago by the American Society of Animal Production on November 30, 1952. Arthur D. Weber was the Honor Guest of the Society during its Annual Meeting which was being held at that time.

ARTHUR D. WEBER

HONOR GUEST—1952

Arthur D. Weber was born on a farm near Muscotah, Kansas, June 17, 1898. He received the B.S. degree in Animal Husbandry in 1922 and the M.S. degree in 1926, both from Kansas State College. He received the Ph.D. degree in Animal Husbandry from Purdue University in 1940. In 1950 Purdue University bestowed upon him the Honorary Doctor of Science Degree.

As a student, Weber worked with the College livestock and lived at one of the College barns. As acting herdsman he exhibited the Kansas State College show cattle at the major livestock shows in 1920. After graduation he became manager of Cameston Farms producing Poland China hogs and Hereford cattle, from 1922 to 1924. In 1924 he returned to teach animal husbandry at Kansas State College where he was responsible for swine research in the Department of Animal Husbandry. The University of Nebraska employed him in 1926 and placed him in charge of sheep in the Department of Animal Husbandry, where he rendered valuable service in the fields of sheep breeding, nutrition, and management for five years. Doctor Weber returned to Kansas State College in 1931 where he assumed full responsibility for the beef cattle work. In 1944 he was made Head of the Department of Animal Husbandry, in which capacity he served until January 1, 1950 when he became Associate Dean of Agriculture and Associate Director of the Kansas Agricultural Experiment Station. He assumed full responsibilities as Dean and Director July 1, 1952.

Dr. Weber has been extraordinarily versatile in the contributions he has made to the livestock industry. Perhaps his greatest contribution has been his research in the fields of breeding, nutrition, and management of all the three classes of meat animals. He has shown exceptional ability to remain conversant with practical problems of the industry while at the same time playing a leading role in research into the more fundamental phases of animal production. He has proved himself to be an outstanding teacher of animal husbandry to undergraduate and graduate students alike and his services have been sought widely by farmers and livestock producers for many years.

Doctor Weber has served well the American Society of Animal Production which has honored him. He was its secretary-treasurer in 1941–42 and national president in 1945–46. He was the first business manager of the JOURNAL OF ANIMAL SCIENCE.

HAROLD H. COLE

Harold H. Cole received the seventh Morrison Award which was presented to him during the 44th Annual Meeting of the American Society of Animal Production in Chicago on November 29, 1952.

THE MORRISON AWARD

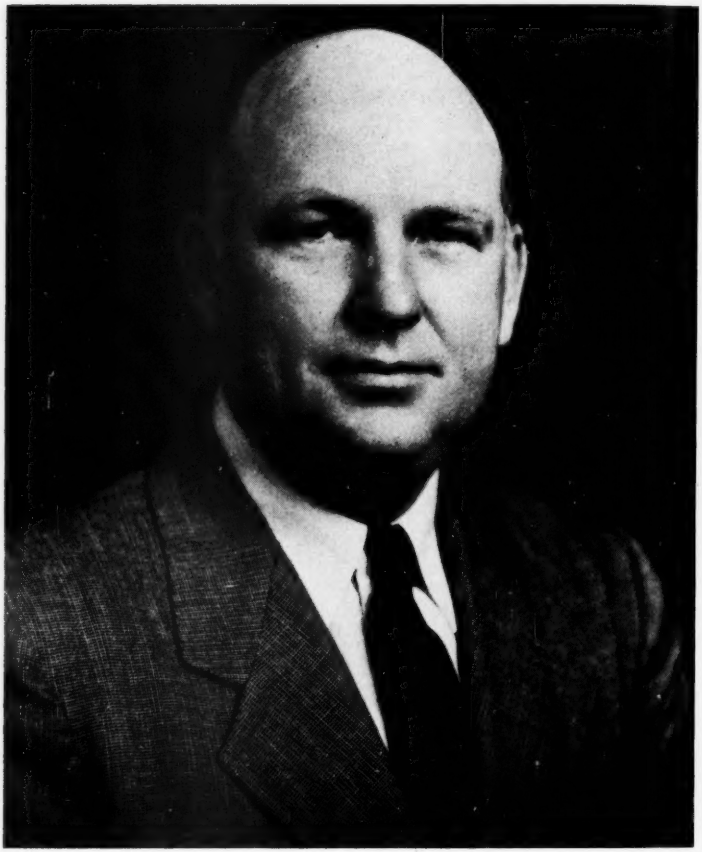
1952

The Morrison Award Committee of the American Society of Animal Production selected Harold H. Cole, of the University of California at Davis as the recipient of the Morrison Award for 1952.

Dr. Cole's research activity has dealt primarily with reproductive and ruminant physiology. His early work was devoted to a study of the estrous cycle of the bitch, ewe and cow. His discovery and subsequent investigations of equine gonadotrophin have contributed greatly not only to our basic knowledge of reproduction but also to the use of gonadotrophin in the treatment of sterility and the experimental control of estrus in domestic animals. His investigations of rumen function have advanced our understanding of the nature, cause and treatment of bloat. In all his researches he has kept well in mind the application of results to the practical livestock man.

Dr. Cole was born on a Wisconsin farm in 1897. He was graduated with the B.S. degree from the University of Wisconsin in 1920. In 1924 he went to the University of California primarily interested in advanced studies in dairy cattle production. While there his interest in physiology was aroused. He was awarded the M.S. at California in 1925 and the Ph.D. in physiology from the University of Minnesota in 1928. Following graduation from Minnesota he returned to California as Assistant Professor of Animal Husbandry. He was advanced to the Professorship in 1943 and was appointed chairman of the department in 1952.

Dr. Cole is recognized not only for his research but as an able teacher and a forceful lecturer who has provided the stimulus for many of his students to elect animal physiology as their field for advanced study.



WILLIAM MALCOLM BEESON

William Malcolm Beeson was awarded the fifth American Feed Manufacturers' Award, which was presented to him during the 44th Annual Meeting of the American Society of Animal Production in Chicago on November 29, 1952.

AMERICAN FEED MANUFACTURERS ASSOCIATION AWARD

1952

William Malcolm Beeson, the 1952 American Feed Manufacturers' Association Award winner, was born in Meridian, Mississippi in 1911. He was graduated with a B.S. degree from Oklahoma A. and M. College in 1931, received his M.S. from Wisconsin in 1932 and his Ph.D. from Wisconsin in 1935. While working on his doctorate, he was an assistant in the Animal Husbandry Department at Wisconsin. In successive years, between 1935 and 1938, he was on the staff at Texas A. and M. College, Idaho, and Arizona. He went back to Idaho as an associate professor in 1938 and remained there until 1945 when he joined the staff at Purdue as professor in charge of Animal Nutrition. Dr. Beeson has been at Purdue since 1945.

Dr. Beeson has published prolifically in the field of swine, beef cattle, and sheep nutrition. Much of his work has been basic to the understanding of the physiological factors involved in the production and reproduction of livestock and in their ability to produce economically meat of high quality. Thus, many of his researches have been concerned with the physiological effects of nutrient deficiencies, such as specific mineral elements, vitamins, and amino acids. Physiological responses, as well as the economical value of adding thyroprotein, thiouracil, stilbestrol, and various antibiotics to practical rations have been studied also by him. His researches on the precise requirements of animals for amino acids and vitamins have led to the formulation of highly efficient rations for various classes of livestock.

The excellence of Dr. Beeson's work may be attributed (1) to the conception of definite ideas; (2) the careful planning and execution of his experiments which often involve the cooperation of a physiologist and a biochemist; and (3) the careful analysis of the results obtained. Thus, his researches have had that characteristic which all researches should have—permanency.

CHAIRMEN OF COMMITTEES, PROGRAM CHAIRMEN, AND SPECIAL ASSIGNMENTS FOR 1953

Standing Committees

Committee on Investigation.....C. M. Kincaid
Committee on Instruction.....T. S. Sutton
Committee on Extension.....E. S. Matteson
Committee on Membership.....A. E. Darlow

Special Committees

Committee on Information.....R. C. Pollock
Committee on Necrology.....A. E. Cullison
Committee on Nominations.....P. S. Shearer
Committee on Morrison Award.....A. E. Darlow
Committee on American Feed Manufacturers Award.....L. E. Hanson
Committee on Registration and Facilities.....J. I. Miller

Program Committees

Breeding and Genetics.....J. A. Whatley, Jr.
Extension .....E. S. Matteson
Meats .....R. L. Hiner
Nutrition .....Elliott Barrick
Pastures and Forages.....J. T. Reid
Physiology .....D. T. Mayer

Special Representatives

Inter-Society Association Council.....E. A. Livesay
American Association for Advancement of Science Council.....L. N. Hazel
Agricultural Research Institute.....J. O. Grandstaff
Division of Biology and Agriculture, NRC.....H. W. Marston
European Animal Husbandry Association.....R. W. Phillips
Ralston Purina Award Committee.....R. H. Nelson

NEWS AND NOTES

Applications for the Ralston-Purina research fellowship should be on file by March 1. Application blanks may be obtained from the Ralston-Purina Research Awards Committee in care of Mr. J. D. Sykes, Ralston-Purina Co., St. Louis, Missouri. The fellowships are for $1440 annually and awards will be made in the fields of nutrition and physiology research as applied to dairy, poultry, and animal husbandry, and in research in transmissible diseases of livestock and poultry. Individuals qualified for graduate study in any Land-Grant Agriculture College and approved Veterinary Colleges are eligible.

The Second Inter-American meeting of Livestock Production convened jointly by the Food and Agriculture Organization of the United Nations and the Inter-American Institute of Agricultural Sciences was held in the city of Baurie, State of Sao Paulo, Brazil, December 8–15, 1952. A total of seventeen nations was represented. The meeting elected João Soares Verga, of Brazil, as its chairman, and Luis Escalõn, of El Salvador, and Mario Lusiardo, of Uruguay, as its Vice-chairmen.

The technical discussions were carried out for the most part in three sectional meetings dealing respectively with animal breeding, animal nutrition, feeding and management and veterinary problems. B. T. Simms, Chief, Bureau of Animal Industry, was chairman of the section on Veterinary Problems. FAO provided a group of consultants composed of A. T. Semple, Thomas Dalling, Ralph W. Phillips and S. H. Work of FAO's Agricultural Division; Douglas H. K. Lee of Johns Hopkins University and Orlando Olcese of the National Agricultural College of La Molina, Peru. Proceedings of the meeting are expected to be ready for distribution in March.

A curriculum in range management has been approved at the University of California. The curriculum is designed to give students broad training and to qualify them as managers of ranch properties, as farm advisors, as range technicians in state and federal agencies, and for graduate studies leading to positions in teaching and research. Heretofore, range management courses have been offered in the School of Forestry and the Department of Agronomy curricula. The new curriculum, which offers a degree in range management, will require that the student spend one of his upper division years on the Davis campus of the University where he will take principally animal husbandry and agronomy courses, and the other on the Berkeley campus where he will take courses in range management and forestry. The first two years of the curriculum offer a broad basic training made up of courses which can be obtained in most colleges, while the second two years are devoted chiefly to professional courses. The curriculum is administered by a committee composed of representatives of the Departments of Agronomy and Animal Husbandry on the Davis campus, and the School of Forestry on the Berkeley campus.

A. L. Musson, former Assistant Professor of Animal Husbandry at Iowa State College, has been appointed Professor and Head of the Department of Animal Husbandry at the South Dakota State College and Agricultural Experiment Station. In the latter position he succeeded R. F. Wilson, now Associate Professor of Animal Husbandry at the Ohio Agricultural Experiment Station.

R. C. Wahlstrom has been appointed Associate Professor and Associate Animal Husbandman at the South Dakota State College and Agricultural Experiment Station.

Bradford Knapp accepted an appointment as Animal Husbandry Technician in Egypt under the Point IV program. He has since been appointed as Chief of the Animal Husbandry Mission there in Cairo.

Irwin A. Dyer, formerly Associate Professor at the University of Georgia,

recently accepted a position with the Technical Cooperation Administration as Research Specialist, Animal Husbandry, in San Salvador, El Salvador.

Pasture Production and Management by R. H. Lush has been published by the Blakiston Co., New York. This textbook emphasizes pasture production and the many factors involved in maintenance, management and nutritive values under the broad concept of grassland farming. There are separate chapters on pasture management of each class of livestock, on irrigation, utilization for hay, silage, soil improvement and seed production, pasture pests, weed control and demonstration tests.

W. A. Cowan, former Assistant Professor of Animal Husbandry at the University of Massachusetts, has been made head of the Department of Animal Industries, University of Connecticut.

William Jackson, former Assistant Chief of the Animal Husbandry Division, Bureau of Animal Industry, Beltsville, Maryland, and more recently Superintendent of the Chinsegut Hill Sanctuary, Brooksville, Florida, retired July 1, 1952 after 34 years in the Bureau. He has been succeeded at Brooksville by Marion W. Hazen, formerly in beef cattle research for the Bureau in cooperation with the Texas Agricultural Experiment Station at Bluebonnet Farms, McGregor, Texas.

Stanley W. Smith, formerly Superintendent of the U. S. Sheep Experiment Station, Dubois, Idaho, and more recently in Agricultural Extension in Idaho, was appointed Director of the Southwestern Range and Sheep Breeding Laboratory, Fort Wingate, New Mexico, in July, 1952.

P. O. Stratton has been appointed Assistant Professor of Animal Breeding in the Department of Animal Production at the Wyoming Agricultural Experiment Station.

Diseases of Poultry by Hungerford was announced by Anglobooks, New York, in December, 1952. The earlier edition has been rewritten. The author attempts to cover all available information as to causation, symptoms, post-mortem appearances, and the control and treatment of all diseases affecting fowls raised for commercial purposes in Australia.

H. Teague, who recently obtained his Doctorate in Genetics at the University of Minnesota, has joined the staff of the Department of Animal Science at the Ohio Agricultural Experiment Station.

L. C. Aicher is now Professor of Animal Husbandry in the Animal Husbandry Department at the Kansas Agricultural Experiment Station. He was former Superintendent of the Fort Hays Branch Station.

R. P. Soule has been appointed Assistant Professor of Animal Husbandry in Meats at Kansas State College and Agricultural Experiment Station.

V. E. McAdams is now Assistant Professor of Animal Husbandry at Kansas State College.

Edward James Stone has been appointed Assistant Dairy Husbandman at the North Louisiana Hill Farm Experiment Station, a branch of the Louisiana Agricultural Experiment Station.

Arthur V. Davis is now Research Associate in Animal Husbandry at the North Louisiana Experiment Station located at Calhoun.

E. D. Leffel has been appointed Assistant Professor in the Animal Husbandry Department, University of Maryland.

James C. Nolan is now Research Assistant in the Department of Animal Production at the Wyoming Agricultural Experiment Station.

I. W. Slater has been appointed Extension Dairyman at the University of Wyoming.

G. A. Allen, Jr., K. X. Williamson, and H. C. Henderson have been appointed to the position of Associate Animal Husbandman at the Virginia Agricultural Experiment Station.

V. K. Johnson and J. A. Welch have been appointed to the position of Assistant Professor and Assistant Animal Husbandman in the Animal Husbandry Department at the West Virginia Agricultural Experiment Station.

Statistical Theory in Research by Anderson and Bancroft was published by McGraw-Hill Book Co., New York, in October, 1952. It is intended to be a combined text book in mathematical statistics and a reference book for the research worker. It is divided into two parts, the first dealing with basic statistical theory and the second with analysis of experimental models by least squares.

M. P. Botkin and E. P. Margerum have been appointed to the position of Assistant Professor in the Department of Animal Production at the University of Wyoming and Agricultural Experiment Station.

J. E. Botcher has been appointed Instructor in the Department of Animal Industry and Range Management at the Montana State College.

A. Grant has been appointed Research Assistant in Animal Industry at the University of Connecticut.

J. E. Rousseau, Jr. is now Research Technician in the Department of Animal Industry at the University of Connecticut.

R. W. Seerley has been appointed Junior Assistant Animal Husbandman in Extension at Purdue University.

Joseph T. Blake has been appointed Instructor of Dairy Husbandry in the Animal Husbandry Department at the Iowa State College.

Methods of Statistical Analysis by Goulden, 2nd edition, was published by John Wiley & Sons, New York, in October, 1952. Much new material has been included in this completely revised edition. It covers the general field of applied statistics with pronounced emphasis on experimental design.

William Hale is now Assistant Professor in the Department of Animal Husbandry at the Iowa State College and Agricultural Experiment Station.

W. E. Thomas, former Assistant Professor of Nutrition at the Kentucky Agricultural Experiment Station, is now operating a large livestock farm in New Jersey.

Hog Profits for Farmers by W. N. McMillen was published by Windsor Press of Popular Mechanics, Chicago, Illinois, in July. This new handbook is illustrated and covers all phases of swine production.

R. G. Warner is now Assistant Professor in the Animal Husbandry Department at Cornell University and Agricultural Experiment Station.

Recent additions in Dairy Extension at North Carolina State College include George Hyatt, Jr., Professor; T. C. Blaylock, Associate Professor; and T. D. George, Assistant Professor.

R. E. Chiles and W. W. Miller have been appointed Extension Livestock Specialists at the Oklahoma Agricultural and Mechanical College.

The Structure of the Meat Animals by MacGregor was announced by Anglobooks, New York, in October, 1952. It is intended to be a guide to the anatomy and physiology of meat animals presented as basic principles for butchers.

R. L. C. de Baca has been appointed Research Assistant in Dairy Husbandry at Oregon State College.

David L. Thacker has been appointed Instructor in Dairy Husbandry at the Pennsylvania State College and Agricultural Experiment Station.

H. L. Mann is now Instructor in Dairy Husbandry Extension at Pennsylvania State College.

S. G. Woods has been appointed Assistant Animal Husbandman at Coast Experiment Station, Summerville, S. C., a branch of the South Carolina Agricultural Experiment Station. He succeeds J. A. McCommas.

Soil Microbiology by Waksman was published by John Wiley and Sons Inc., New York, in October, 1952. The aims of the book are to survey the nature and abundance of microorganisms in the soil and their relation to soil fertility.

J. W. Kelly has been appointed Assistant in Dairying at the South Carolina Agricultural Experiment Station.

F. W. Crandall has succeeded J. L. Leibel as Instructor and Assistant Animal Husbandman in the Department of Animal Husbandry at the South Dakota Agricultural Experiment Station.

LaVerne Kartan is now Assistant Extension Animal Husbandman at the South Dakota State College.

J. H. Carrier, W. T. Flatt and H. E. Galey have been appointed to the position of Assistant Animal Husbandman in the Animal Husbandry Department at the University of Tennessee.

Thomas C. Cartwright has been employed as Assistant Animal Husbandman and Geneticist at Bluebonnet Farm, McGregor, Texas, a branch of the Texas Agricultural Experiment Station.

James E. Ingal's has been appointed Assistant Animal Husbandman at the San Juan Branch Station of the Colorado Agricultural Experiment Station.

Grasses and Grassland Farming by H. W. Staten was published by Devin-Adair Co., N. Y. in December, 1952. This is a practical discussion of the role of grass in the feeding of livestock and in general farming. Attention is given to extension of the grazing season in different regions of the U. S.

H. M. Hansen has been appointed Assistant Professor of Dairy Husbandry at the Connecticut Agricultural Experiment Station.

E. L. Hix has been appointed Instructor of Animal Husbandry and Animal Husbandry Investigator at the Kansas State College.

Aldon Jensen has been appointed Instructor in Animal Husbandry at the Iowa State College.

Fred C. Powell has returned to the Tennessee Agricultural Experiment Station as Assistant Animal Husbandman, following a period of service in the U. S. Army.

B. B. Gray is now Assistant Animal Husbandman and Herd Manager at the Georgia Agricultural Experiment Station.

C. C. O'Mary has been appointed Assistant Professor of Animal Husbandry at the Georgia Agricultural Experiment Station.

J. V. Craig has been appointed Instructor and First Assistant in the Department of Animal Science at the Illinois Agricultural Experiment Station.

Mrs. Elizabeth E. Schoen has been appointed Assistant Animal Nutritionist at the University of Illinois.

E. U. Dillard, after a year's leave of absence to do work toward the Ph.D. degree under G. E. Dickerson at Missouri, has returned to the Animal Industry Department at North Carolina State College.

J. B. Outhouse, former Associate Professor of Animal Husbandry at the University of Maryland, is working toward a Doctorate at Purdue University and teaching a course in Animal Agriculture. This is a pioneer course for students in agriculture designed to show the place of livestock in the farm program.

M. P. Plumlee has been appointed Junior Assistant Animal Husbandman at the Nebraska Agricultural Experiment Station.

L. C. Uiberg has been appointed Assistant Professor in the Department of Animal Husbandry at Mississippi State College.

INFORMATION FOR CONTRIBUTORS

1. Papers may be submitted reporting work whose ultimate objective is clearly the solution of a livestock production problem and whose contents should be of interest particularly to those dealing with livestock production problems. Review papers on subjects of general interest will also be published at intervals, and will be prepared on invitation by the Editorial Board.

2. All papers will be subject to critical review by the Editorial Board, or others designated by the Editor. Papers needing revision will be returned to authors and should be revised and returned promptly. Papers not suitable for publication will be returned to authors with a statement of reasons for not accepting them.

3. Papers submitted should be based on new and adequate information. The following are guides to style and form:

   (a) Manuscripts must be typed, double-spaced, and the ribbon copy submitted.

   (b) Pages must be numbered. The lines of text must be numbered in the left margin, beginning with one at the top of each page. This does not apply to tabular material.

   (c) Tables should be as few and as simple as is feasible for presentation of the essential data.

   (d) Legend for each figure should be typed on a separate sheet. Photographs should be carefully prepared and labeled. Magnifications of photomicrographs should be indicated on legends. Charts should be prepared in India ink. Typed material on charts is not acceptable. Material that will not reproduce satisfactorily will be returned for revision. For suggestions on preparing illustrative material see the "Style Brief" published by the Wistar Institute Press, Philadelphia. If in doubt, consult the Editor before putting material in finished form.

   (e) The introduction should consist only of a paragraph indicating very briefly the nature of the question asked and the reason for asking it. Reference to relevant literature should be made later in the discussion of the results. Concise presentation of data is desired and there should be evidence of statistical examination wherever obviously useful in the interpretation. Unsupported hypotheses should be avoided. The organization of a manuscript may vary with the nature of the material, but all manuscripts should contain a clear statement of application of the results or their relation to some problem of the livestock industry. Each paper should end with a brief summary in the form of an abstract containing the most pertinent data in the briefest possible form.

   (f) Literature citations must be listed in alphabetical order and should be referred to in the text by author and date, i.e., Castle (1924), or (Castle, 1924). Citations may be referred to by number in review articles where the number of citations is too great to permit convenient use of the above form. "Literature cited" lists should be typed in a style used in a current issue of the JOURNAL.

4. Manuscripts will be edited in the order received, and accepted papers will be published as nearly in this order as feasible.

J. W. Kelly has been appointed Assistant in Dairying at the South Carolina Agricultural Experiment Station.

F. W. Crandall has succeeded J. L. Leibel as Instructor and Assistant Animal Husbandman in the Department of Animal Husbandry at the South Dakota Agricultural Experiment Station.

LaVerne Kartan is now Assistant Extension Animal Husbandman at the South Dakota State College.

J. H. Carrier, W. T. Flatt and H. E. Galey have been appointed to the position of Assistant Animal Husbandman in the Animal Husbandry Department at the University of Tennessee.

Thomas C. Cartwright has been employed as Assistant Animal Husbandman and Geneticist at Bluebonnet Farm, McGregor, Texas, a branch of the Texas Agricultural Experiment Station.

James E. Ingal's has been appointed Assistant Animal Husbandman at the San Juan Branch Station of the Colorado Agricultural Experiment Station.

Grasses and Grassland Farming by H. W. Staten was published by Devin-Adair Co., N. Y. in December, 1952. This is a practical discussion of the role of grass in the feeding of livestock and in general farming. Attention is given to extension of the grazing season in different regions of the U. S.

H. M. Hansen has been appointed Assistant Professor of Dairy Husbandry at the Connecticut Agricultural Experiment Station.

E. L. Hix has been appointed Instructor of Animal Husbandry and Animal Husbandry Investigator at the Kansas State College.

Aldon Jensen has been appointed Instructor in Animal Husbandry at the Iowa State College.

Fred C. Powell has returned to the Tennessee Agricultural Experiment Station as Assistant Animal Husbandman, following a period of service in the U. S. Army.

B. B. Gray is now Assistant Animal Husbandman and Herd Manager at the Georgia Agricultural Experiment Station.

C. C. O'Mary has been appointed Assistant Professor of Animal Husbandry at the Georgia Agricultural Experiment Station.

J. V. Craig has been appointed Instructor and First Assistant in the Department of Animal Science at the Illinois Agricultural Experiment Station.

Mrs. Elizabeth E. Schoen has been appointed Assistant Animal Nutritionist at the University of Illinois.

E. U. Dillard, after a year's leave of absence to do work toward the Ph.D. degree under G. E. Dickerson at Missouri, has returned to the Animal Industry Department at North Carolina State College.

J. B. Outhouse, former Associate Professor of Animal Husbandry at the University of Maryland, is working toward a Doctorate at Purdue University and teaching a course in Animal Agriculture. This is a pioneer course for students in agriculture designed to show the place of livestock in the farm program.

M. P. Plumlee has been appointed Junior Assistant Animal Husbandman at the Nebraska Agricultural Experiment Station.

L. C. Uiberg has been appointed Assistant Professor in the Department of Animal Husbandry at Mississippi State College.

INFORMATION FOR CONTRIBUTORS

1. Papers may be submitted reporting work whose ultimate objective is clearly the solution of a livestock production problem and whose contents should be of interest particularly to those dealing with livestock production problems. Review papers on subjects of general interest will also be published at intervals, and will be prepared on invitation by the Editorial Board.

2. All papers will be subject to critical review by the Editorial Board, or others designated by the Editor. Papers needing revision will be returned to authors and should be revised and returned promptly. Papers not suitable for publication will be returned to authors with a statement of reasons for not accepting them.

3. Papers submitted should be based on new and adequate information. The following are guides to style and form:

   (a) Manuscripts must be typed, double-spaced, and the ribbon copy submitted.

   (b) Pages must be numbered. The lines of text must be numbered in the left margin, beginning with one at the top of each page. This does not apply to tabular material.

   (c) Tables should be as few and as simple as is feasible for presentation of the essential data.

   (d) Legend for each figure should be typed on a separate sheet. Photographs should be carefully prepared and labeled. Magnifications of photomicrographs should be indicated on legends. Charts should be prepared in India ink. Typed material on charts is not acceptable. Material that will not reproduce satisfactorily will be returned for revision. For suggestions on preparing illustrative material see the "Style Brief" published by the Wistar Institute Press, Philadelphia. If in doubt, consult the Editor before putting material in finished form.

   (e) The introduction should consist only of a paragraph indicating very briefly the nature of the question asked and the reason for asking it. Reference to relevant literature should be made later in the discussion of the results. Concise presentation of data is desired and there should be evidence of statistical examination wherever obviously useful in the interpretation. Unsupported hypotheses should be avoided. The organization of a manuscript may vary with the nature of the material, but all manuscripts should contain a clear statement of application of the results or their relation to some problem of the livestock industry. Each paper should end with a brief summary in the form of an abstract containing the most pertinent data in the briefest possible form.

   (f) Literature citations must be listed in alphabetical order and should be referred to in the text by author and date, i.e., Castle (1924), or (Castle, 1924). Citations may be referred to by number in review articles where the number of citations is too great to permit convenient use of the above form. "Literature cited" lists should be typed in a style used in a current issue of the JOURNAL.

4. Manuscripts will be edited in the order received, and accepted papers will be published as nearly in this order as feasible.

5. There will be a charge for making engravings in excess of one page per paper and of printing tables in excess of two pages per paper. The author will be asked when his manuscript is accepted to indicate the institution, agency or individual that will assume responsibility for the charges and for the reprints ordered at that time.

6. Authors will receive galley proof of articles together with a form for supplying an abstract for "Biological Abstracts". *Corrected proof and abstract should be mailed to the Editor within three days after they are received. Failure to do this may result in delay of publication until the next issue.*

7. One author of each manuscript should be a member of the Society. Papers by non-members can be published only after approval by the Executive Committee.

8. A "News and Notes" section will be published in each issue, including Society announcements, changes in positions and other items of professional interest concerning the members, and other items of interest to the membership. All such items should be sent promptly to the Editor.

9. Abstracts of papers to be presented at the annual meetings of the Society will be published in the November issue. Such abstracts must not exceed 250 words in length, should be typed (double spaced) and the ribbon copy submitted, the lines on the page should be numbered, in the left margin, from top to bottom, and must be in the hands of the Secretary of the Society by August 15, preceding the meeting. These abstracts must be summaries of results and conclusions.

10. Presentation of a paper at the annual meeting does not exclude it from publication in complete form in the JOURNAL. Such papers may be submitted to the Editor and will be given equal consideration with others submitted.

11. All manuscripts and correspondence concerning them should be addressed to the Editor: Dr. L. E. Casida, Department of Genetics, University of Wisconsin, Madison, Wisconsin, or to the publishers: Boyd Printing Company, 372-374 Broadway, Albany 7, New York.

12. All correspondence concerning subscriptions to the JOURNAL OF ANIMAL SCIENCE and other business matters should be addressed to the Business Manager, Dr. J. I. Miller, Department of Animal Husbandry, Cornell University, Ithaca, N. Y., or to the publishers, Boyd Printing Company, 372-374 Broadway, Albany 7, New York.